# RESEARCH REPORT

## HOUSING AND POPULATION HEALTH: A REVIEW OF THE LITERATURE

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# *Housing and Population Health: A Review of the Literature*

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# PURPOSE

Population health is a way of thinking about and acting on health. Rather than focusing on diagnosis of disease and its remedy, population health focuses on why some subgroups of society are predisposed to be ill in the first place. A number of studies have established that, of the major factors which determine the health and well-being of society, health care is not dominant. Important determinants include individuals' behaviours and their genetic inheritance, as could be expected. But the physical environment and especially the social environment, including such things as income, education, social status, social networks and support environments, are also important.

The concept of population health has been endorsed by the federal and provincial governments and by a number of health forums. Its inclusion in nationwide health information systems, and a system of population health accounts, have been suggested, as has a research agenda which involves health impact assessment of nonmedical determinants of health. In support of this, CMHC is interested in a better assessment of the effect of housing on the population's health, with an emphasis on the need to demonstrate hard evidence.

It is quite plausible that housing is indeed a significant factor in health because it provides both a physical and a social environment. On the first count, there is already a substantial body of work (mainly British) which has established many links between poor physical conditions in housing and incidence of disease. On the second count, the social environment, there is less evidence.

This report aims to critically review the established literature with two objectives. One is to assess what is known on housing and health, and to what degree. The other is to come to an appreciation of the difficulties of getting to know things in this area.

# ABSTRACT

This paper reviews the strength of evidence in the established literature that links housing to health, especially population health and comments on the state of the art.

The literature was screened for scientific robustness before the assessment. Two distinct categories of literature are apparent. The larger category has to do with chemical, biological and radiation exposures which occur primarily or frequently in the household setting. A smaller category has to do with sociological concepts and physical design. Overall, 24 housing exposures or factors were identified, leading to 40 health effects, about a quarter of them judged to be definitively or strongly linked.

All the definitive or strong links were found in the first category. Here, research methods come from the disciplines of environmental and occupational health and take place within an established theoretical framework involving quantitative exposure assessment, measurement of defined physiological parameters and health outcomes, and calculation of the dose-response relationship between exposure and outcome.

In the second category, research examines complex housing factors such as design and overcrowding that do not easily conform to an experimental model based on exposure to a physical substance. Socioeconomic status and its component parts were noted as a confounding variable which strongly influences both the health status of the individuals in a household and in the quality of their housing situation.

Generally, the research on the housing/health relationship has not established the relative importance of different housing factors nor looked at the interaction of factors. Methodological difficulties are associated with research which must span different types of disciplines.

There is a lack of a general theory of the mechanisms by which housing affects health. Population health research, while acknowledging the importance of the social and physical environment, rarely specifies housing. Very little attention has been paid to measuring how far, and in what way, better housing might improve public health.

# Executive Summary

The field of population health poses a critical question for society: what determines health? (and thus how can health be promoted and how can resources be best targeted for further health gains).

Collective health has improved in developed countries over the past century. It is generally agreed that the major reasons include increased prosperity, better nutrition, improved medical services, and improved conditions in the social and physical environment.

Since housing is a major contributor to both social and physical environments, it seems logical that housing would be a major contributor to health as well.

This paper critically reviewed the evidence linking housing to health. It found that research into the relationship between housing and health has tended to be narrowly focused, fragmented, and its practical relevance to either housing or health studies has been only marginal. Population health research, in its reference to the importance of the social and physical environment, rarely specifies housing. Very little attention has been paid to measuring how far, and in what way, better housing might improve public health.

A search of the established literature disclosed four main categories of exposure to housing factors that might be inimical to health: specific physical or chemical exposures (e.g., lead, radon); specific biological exposures (e.g., dampness and mold, dust mites); physical characteristics of the house (e.g., housing design, overcrowding); and social, economic, and cultural characteristics of housing (e.g., housing tenure, housing satisfaction).

Most of the housing/health literature referred to the physical house. Other concepts of housing found in sociological literature were rarely distinguished; these would include: the home – the social and psychological aspects of the house, the neighbourhood – the immediate physical area around the house and home, and the community – the social characteristics and range of important services in a neighbourhood.

A major difficulty of research in this area is the role of socioeconomic status (SES) of a household which strongly influences both the health status of the individuals in a household and in the quality of their housing situation. Research has established that people with low SES in a society tend to be less healthy and to die earlier then people with a high SES. Another difficulty is that research on the topic has been focused on the effect of housing on health without recognizing that there is a two-way relationship. Health of individuals can affect the type of housing they live in as well. Neither has research on the housing/health relationship established the relative importance of different housing factors nor looked at the interaction of factors.

## Summary of Findings

Much of the general literature on the effects of housing on health cites previous studies and provides no original data on the connection between health and housing. Because of the lack of a general theory of the mechanisms by which housing affects population health, serious methodological difficulties are associated with multidisciplinary research on the topic.

Studies providing original data on the relationship between housing and health can be divided into two main types. The first involves the study of specific physical, chemical, and biological exposures with a known or suspected effect on health, and which occur primarily or frequently in the household setting. Prototypical exposures in this category include lead and radon. Research methods come from the disciplines of environmental and occupational health and take place within an established theoretical framework involving quantitative exposure assessment, measurement of defined physiological parameters and health outcomes, and calculation of the dose-response relationship between exposure and outcome.

The second type of research on the relationship between housing and health has focused on built-in characteristics of housing, and social, economic and cultural factors. Many studies of this type examine complex housing factors such as design and overcrowding that do not easily conform to an experimental model based on exposure to a physical substance. In part because of the lack of a clear experimental model, research of this type has not been as extensive or systematic as in the first.

Overall, 24 housing exposures or factors were identified, leading to 40 health effects. In assessing the overall strength of evidence of a housing/health link, studies that used stronger research designs were given greater weight because they are more likely to give reliable and trustworthy results with less bias and error. They were: cross-sectional studies, case-control studies, cohort or longitudinal studies, and randomized controlled trials.

Following assessment, the strength of the evidence supporting a causal relationship was classified as: definitive, strong, possible or weak.

| Category of housing exposure/ factor | Number of identified exposures | Number of studied health effects | | | | Total # of effects |
|---|---|---|---|---|---|---|
| | | Definitive | Strong | Possible | Weak | |
| chemical exposures | 5 | 2½ | ½ | 1 | 1 | 5 |
| biological exposures | 3 | 1 | 1 | 5 | 0 | 7 |
| physical characteristics | 14 | 4½ | 2 | 15½ | 0 | 22 |
| social, economic & cultural factors | 2 | 0 | 0 | 5 | 1 | 6 |
| Total | 24 | 8 | 3½ | 26½ | 2 | 40 |

## Does Housing Affect Health?

Merely observing associations between housing factors and population health does not provide convincing evidence of causation if there is no clear mechanistic explanation linking the (supposed) causative factor to the effect. Research into the social, economic, and cultural characteristics paid little attention to causation with the following shortcomings.

- As long as mechanisms remain uncertain, it is entirely possible that much of the correlation between housing and population health is due to confounding by other factors, such as socioeconomic status.
- Knowledge about mechanisms greatly enhances the ability of researchers to focus on and measure relevant exposures and outcomes.
- Identifying specific mechanisms that link housing to health facilitates the development of effective housing interventions to improve health.

There are several reasons why mechanisms are better defined in relation to physical, chemical, and biological exposures and physical characteristics of housing than in relation to social, economic, and cultural characteristics of housing.

- Some housing factors are more easily defined and quantified (for example, lead concentrations measured in parts per million, or the presence or absence of a smoke detector) than others (for example, housing density or housing affordability).
- Medical research techniques are more highly developed in the areas of physiology in comparison with psychology.

By their very nature, social, economic, and cultural housing factors are multidimensional, interrelated and therefore more complex. Any effort to isolate a single mechanism by which any of these factors exerts an influence on a specific health outcome is extremely difficult if not impossible. This problem is inherent in the study of any socioeconomic determinants of health and is not limited to the area of housing.

## Can Housing Interventions be Considered Worthwhile Health Interventions?

Where the housing/health relationship is definitive, and an improvement in the housing factor is known to result in an improvement in the corresponding health effect, the next question is whether the housing intervention is cost-effective. In other words, the value of the health gain should be weighed against the cost of the intervention. The established literature did not deal with this question; estimates of the size of the Canadian population exposed to each factor were not considered, and the magnitude of the health effects of each factor was also uncertain in most cases. Because of these two factors, the relative "seriousness" of the various hazards could not be reliably ranked.

Housing interventions to improve population health are most likely to have an effect when they target those who are at highest risk for adverse health outcomes or have the greatest exposure to the risk factor. In most cases, this means focusing on the poor. For example, one can expect greater health gains from spending $1000 to improve a substandard house on an Aboriginal reserve than spending the same amount on a middle-class house in Toronto. Thus, studies of the effectiveness and cost-effectiveness of housing as a health intervention should focus on vulnerable populations, including the poor and people living in low-quality housing. This approach would also identify the groups least likely to achieve meaningful improvements in their housing status in the absence of systematic interventions. Research in this area would be a natural outgrowth of program evaluations of housing interventions through inclusion of health effects as a possible outcome.

# Résumé

Une question fondamentale se pose au sujet de la santé de la population : qu'est-ce qui détermine la santé? (et partant, comment peut-on promouvoir la santé et mieux cibler les ressources pour l'améliorer). Au cours des cent dernières années, la santé collective a connu une progression dans les pays développés. On s'entend généralement sur les principales raisons suivantes : une prospérité accrue, une meilleure nutrition, les progrès de la médecine et des conditions plus favorables dans l'environnement social et physique. Puisque le logement contribue en grande partie aux environnements social et physique, il semble logique qu'il en fasse de même pour la santé.

Dans ce document on a analysé de façon éclairée les preuves d'un lien entre le logement et la santé. On a déterminé que la recherche entreprise pour trouver la relation qui existe entre le logement et la santé avait tendance à être plus étroitement délimitée, fragmentée et que sa pertinence pratique a été négligeable, tant pour les études relatives au logement qu'à la santé. Dans la recherche concernant la santé de la population, on cite rarement le logement par rapport à l'importance des milieux social et physique. On s'est bien peu occupé de savoir dans quelle mesure et de quelle façon un meilleur logement pourrait améliorer la santé publique.

L'étude de la documentation reconnue, a permis de distinguer quatre catégories principales de facteurs risques que pose le logement pour la santé : contact avec des agents physiques ou chimiques spécifiques (p. ex. le plomb, le radon ) ; contact avec des éléments biologiques spécifiques (p. ex. l'humidité et les moisissures , les acariens détriticoles); les caractéristiques physiques de la maison (p.ex. la conception de l'habitation, le surpeuplement); et les caractéristiques sociales, économiques et culturelles du logement (p. ex. mode d'occupation, satisfaction relative au logement).

La plupart de la documentation sur le logement/la santé concernait le bâtiment lui-même. On relevait rarement les autres concepts de logement figurant dans les documents sociologiques, notamment les suivants : la maison - les aspects sociaux et psychologiques de la maison, le quartier - le secteur immédiat du logement et la collectivité - les caractéristiques sociales et le choix des services importants dans un quartier.

La recherche dans ce domaine présentait une grande difficulté à savoir le rôle de la situation socioéconomique (SSE) d'un ménage qui influe fortement tant sur l'état de santé de ses membres que sur la qualité de leur situation de logement. La recherche a permis de déterminer que les personnes qui ont une faible SSE dans une société tendent à être en moins bonne santé et à décéder plus tôt que les gens dont la SSE est élevée. Une autre difficulté provient du fait que la recherche sur le sujet s'est focalisée sur l'effet que le logement a sur la santé, sans reconnaître que la relation va dans les deux sens. La santé des gens peut aussi influer sur le type de logement dans lequel ils vivent. La recherche n'a pas permis non plus de déterminer l'importance relative des différents facteurs de logement, ni examiné leur interaction.

## *Résumé des constatations*

Dans une bonne partie de la documentation générale concernant les effets du logement sur la santé, on cite les études déjà réalisées et on ne fournit aucune donnée originale sur le rapport entre la santé et le logement. Faute de théorie générale sur les mécanismes selon lesquels le logement influe sur la santé de la population, de sérieuses difficultés de méthodologie entravent la recherche multidisciplinaire sur le sujet.

On peut répartir en deux principales catégories les études apportant des données originales sur le rapport entre le logement et la santé. La première comprend l'étude des contacts physiques, chimiques et biologiques spécifiques, ayant un effet connu ou soupçonné sur la santé et qui se présentent surtout ou souvent dans un logement.

Dans cette catégorie les contacts prototypiques comprennent le plomb et le radon. Les méthodes de recherche sont empruntées aux disciplines de la santé environnementale et au travail et sont utilisées dans un cadre théorique établi comprenant l'évaluation quantitative du contact, la mesure de paramètres physiologiques définis et les résultats en matière de santé, ainsi que le calcul des rapports et la dose-réponse entre le contact et le résultat.

Le deuxième type de recherche sur le rapport entre le logement et la santé est axé sur les caractéristiques intrinsèques du logement et les facteurs sociaux, économiques et culturels. De nombreuses études de ce genre examinent des facteurs de logement complexes, comme la conception du logement et le surpeuplement, lesquels ne se conforment pas facilement à un modèle expérimental fondé sur le contact avec une substance physique. La recherche de ce genre n'est pas aussi approfondie ou systématique que la première, en partie à cause du manque de modèle expérimental précis.

On a relevé au total 24 contacts ou facteurs, entraînant 40 effets sur la santé. Dans l'étude de l'évaluation globale des preuves d'un lien existant entre le logement et la santé, on a accordé davantage de pondération aux études qui utilisaient de plus solides conceptions de recherche parce qu'elles sont censées donner des résultats fiables moins impartiaux et comportant moins d'erreurs. Ce sont les suivantes : études en coupe, études de cas-témoins, études de cohorte et longitudinales, ainsi que des essais aléatoires controllés.

Après évaluation, on a classé les preuves à l'appui d'un rapport causal comme étant : certain, probable, possible et faible.

| Catégorie de contact/facteur dans le logement | Nombre de contacts relevés | Nombre d'effets sur la santé étudiés | | | | Nombre total d'effets |
|---|---|---|---|---|---|---|
| | | Certains | Probables | Possibles | Faibles | |
| Contacts chimiques | 5 | 2½ | ½ | 1 | 1 | 5 |
| Contacts biologiques | 3 | 1 | 1 | 5 | 0 | 7 |
| Caractéristiques physiques | 14 | 4½ | 2 | 15½ | 0 | 22 |
| Facteurs sociaux, économiques & culturels | 2 | 0 | 0 | 5 | 1 | 6 |
| Total | 24 | 8 | 3½ | 26½ | 2 | 40 |

### Le logement influe-t-il sur la santé ?

La simple observation des rapports entre les facteurs de logement et la santé de la population ne fournit pas de preuves convaincantes de causes, si aucune explication mécaniste ne rapproche le facteur causatif (supposé) à l'effet. Dans la recherche sur les caractéristiques sociales, économiques et culturelles, on s'est peu occupé de la cause des lacunes suivantes :

- Tant que les mécanismes sont incertains, il est tout à fait possible qu'une bonne partie de la corrélation entre le logement et la santé de la population soit attribuable à la confusion avec d'autres facteurs, comme une situation socio-économique.
- La connaissance des mécanismes améliore grandement la capacité des chercheurs à se concentrer sur les contacts et les résultats et à les mesurer.
- La définition de mécanismes précis qui lient le logement à la santé facilite le développement d'interventions efficaces en matière d'habitation dans le but d'améliorer la santé.

On peut expliquer de diverses façons le fait que les mécanismes soient mieux définis par rapport aux contacts physiques, chimiques et biologiques et aux caractéristiques physiques du logement qu'en relation avec les caractéristiques sociales, économiques et culturelles du logement.

- On définit et on quantifie plus facilement certains facteurs de logement (par exemple, les concentrations de plomb mesurées en parties par million, ou la présence ou l'absence de détecteur de fumée) que d'autres (par exemple, la densité ou l'abordabilité du logement).
- Les techniques de recherche médicale sont plus élaborées dans les domaines de la physiologie qu'en psychologie.
- En raison de leur nature sociale, économique et culturelle les facteurs de logement sont multidimensionnels, interdépendants et par conséquent plus complexes. Il est très difficile, sinon impossible d'isoler un seul mécanisme selon lequel n'importe

lequel de ces facteurs exerce une influence sur un résultat de santé spécifique. Ce problème est inhérent à l'étude de tout facteur socioéconomique déterminant de la santé et il n'est pas limité au domaine du logement.

## Peut-on considérer les interventions en matière de logement comme valables sur le plan de la santé?

Lorsque le rapport entre le logement et la santé est définitif et qu'on sait qu'une amélioration du facteur logement entraîne une amélioration correspondante de l'effet santé, il faut se demander si l'intervention du logement est rentable. Autrement dit, il faut évaluer la valeur du gain en matière de santé par rapport au coût de l'intervention. La documentation reconnue ne traitait pas cette question; on n'avait pas estimé la taille de la population canadienne exposée à chaque facteur et dans la plupart des cas on ne connaissait pas vraiment l'ampleur des effets de chaque facteur sur la santé. En raison de ces deux facteurs, on n'a pu classer de façon fiable la gravité relative des divers dangers.

Les interventions du logement pour améliorer la santé de la population ont très probablement un effet lorsqu'elles ciblent les personnes qui sont les plus exposées aux effets adverses sur la santé ou au facteur risque. Dans la plupart des cas, cela signifie qu'il faut s'occuper des personnes démunies. Par exemple, on peut s'attendre à des gains plus importants en matière de santé lorsqu'on dépense 1000 $ pour réparer une maison qui ne répond pas aux normes dans une réserve autochtone, qu'en dépensant la même somme dans une maison de la classe moyenne à Toronto. Ainsi, les études de l'efficacité et de la rentabilité du logement en tant qu'intervention sur le plan de la santé devraient s'orienter davantage sur les populations vulnérables, notamment les personnes démunies et celles qui occupent des logements de piètre qualité. Cette approche permettrait également de définir les groupes qui obtiendraient le moins d'améliorations valables de leur situation de logement en l'absence d'interventions systématiques. La recherche dans ce domaine serait une conséquence naturelle des évaluations de programme en matière d'interventions de logement par l'ajout des effets sur la santé comme un résultat possible.

*"Everyone has the right to a standard of living adequate for the health and well-being for himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control "*

Universal Declaration of Human Rights, Article 25,
proclaimed by the United Nations General Assembly on December 10, 1948.

*"it is surprisingly difficult to prove that there is a link between housing and health. For a start, what to study is hard to decide. Housing has no simple definition. To most of us, our house is the "bricks and mortar" of the dwelling in which we live. But depending on the health effect we want to study, we may need to use a much wider definition. If we are interested in the possible effects of housing on chest disease, we need to think of the structure of the building: Is it warm, dry, and well ventilated? ... If we want to study the effects of housing on mental health, we may need to take an even wider view.. Is the house close to shops and other amenities? How much social support is there in the area? Is there a safe play area for the children? By choosing an inappropriate definition of housing, we may miss very real effects. "*

S. Lowry, "Health," *Encyclopedia of Housing*, Sage, 1998, p. 209.

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## 1. Introduction

In their paper on population health, Mustard and Frank identify two critical questions facing society: (1) what determines health (and thus how can health be fostered); and (2) how can health resources be targeted on sectors where it is most cost effective? The primary evidence for the improved collective health of individuals is the increasing life expectancy observed in developed countries over the past century. A great deal of debate remains over the causal factors behind this trend. It is generally agreed that a major role has been played by factors such as increased prosperity, better nutrition, improved medical services, and improved conditions in the social and physical environment. Mustard and Frank highlight the effect of improvements in the social environment (living conditions):

> *The enhanced prosperity of regions leads to better living and working conditions. It is the effect of the social environment that appears to have been key in changing the health status of the population.*

Although their paper mentions the potentially important role played by the social and physical environment, housing is not explicitly mentioned. Research into the relationship between housing and health has frequently been narrowly focused, fragmented, and of marginal practical relevance to either housing or health studies.

In her review of the British literature on housing and health ten years ago, Smith ends with the statement that the "case for developing a co-ordinated, integrated and cumulative body of housing and health research has never, it seems, been stronger." She notes that there is very little formal co-ordination between housing policy and population health policy and very little attention is paid to "measuring how far, and in what way, better housing might improve public health."

Smith argues that the literature indicates that public health objectives can better inform housing policy and that health indicators and outcomes can contribute to the evaluation of housing initiatives. The ways in which housing research may advance our understanding of public health includes:

- illuminating the environmental precursors of disease;
- exposing the mechanisms which "sort" households according to health status into different parts of the housing stock, affecting access to the wide range of employment opportunities, services, and resources that are also unevenly distributed in space; and
- exploring the interface of housing provision and health care policies.

Another practical role for research linking housing conditions and health status is to inform revisions of building codes, municipal bylaws (housing standards, development regulations, etc.), and public and environmental health regulations.

The population health framework is a way of conceptualizing and acting on health . This approach focuses on why some groups in society are more prone to illness than other groups. It is one of the latest approaches to the conceptualization of health and represents a recent shift in emphasis among some in the health field from health promotion to population health Robertson, 1998).

Population health advocates reveal their commitment to and faith in an ultimately biological explanation of health . As Millar and Hull point out, population health is influenced by diverse, interacting factors. There seems to be a consensus that living and working conditions, individual skills and choices, biology and genetic endowment, physical environment, and the health care system act independently and in combination to affect the health of individuals and the population. Some of the powerful factors affecting health and health status include adequacy of income, fair distribution of wealth, availability of jobs, type of employment and work conditions, and the adequacy of housing . Because of the lack of a general theory of the mechanisms by which housing affects population health, serious methodological difficulties are associated with multidisciplinary research on the topic. Despite these obstacles, however, the population health model highlights the importance of further research to elucidate the relationship between housing and health.

## 2. Methodology

This literature review has been carried out for Canada Mortgage and Housing Corporation to document what is currently known about the relationship between housing and health and to understand the influence that housing may have on the health of the Canadian population.

We performed an extensive search of the published literature on housing and health. The key words used in this search were chosen in consultation with members of an advisory committee, an expert in aboriginal issues, an expert in disability issues, and a medical research librarian.

We searched five research databases. The MEDLINE database from January 1984 to April 1998 was searched for all articles with the keyword "housing." Because the MEDLINE database indexes only biomedical and health-related journals, any articles with the keyword "housing" were potentially relevant. We excluded animal studies. This search identified 1,867 abstracts in English or French.

We also searched the following databases: Ageline (1983 to 1998) , Psych-Info (1983 to 1998), Sociological Abstracts (1986 to 1998), and Social Science Abstracts (1983 to 1998). Because these databases index numerous journals that do not have a health-related focus, the search strategy used was different from that used for MEDLINE. We searched for "health" or "illness" or "disease" as text words in conjunction with "housing" as a keyword. These searches yielded an additional 165 references in English or French.

We constructed a database containing all 2,032 abstracts and references. The co-investigators and research assistants reviewed the abstracts. Articles were selected for further review if they appeared to examine a relationship between housing or a specific exposure occurring in the home and any aspect of health. Duplicate references, studies relevant solely to the Third World, and those that did not discuss a relationship between housing and health were eliminated. If it was not clear from the abstract whether or not the article was relevant, we retrieved the full article. This process reduced the number of relevant studies to approximately 600; these articles were retrieved and reviewed in full. During the review process, seminal works published before 1985 were identified. These items were retrieved, increasing the total number of articles to 639.

We then categorized all articles according to the exposure, housing factor, or characteristic studied. We identified four distinct categories:

1. *Specific physical or chemical exposures* (e.g., lead, radon, asbestos, electromagnetic fields, urea formaldehyde insulation);
2. *Specific biological exposures* (e.g., dampness and mould, dust mites, cockroaches);
3. *Physical characteristics of the house* (e.g., housing design, overcrowding, density, indoor air quality);
4. *Social, economic, and cultural characteristics of housing* (e.g., housing tenure, housing satisfaction, housing affordability).

Each exposure or housing factor was allocated to a research associate or co-principal investigator who reviewed all articles on that topic and drafted a summary of the literature. During this process, many of the 639 articles reviewed were found not to contribute substantive information relevant to the goals of this project. We have not referenced these articles in the literature review that follows. Many of these articles examined methodologies for quantifying specific exposures, rather than whether or not the exposure affected health, or were review articles that provided no additional information beyond that contained in the original research articles we had already obtained.

Three highly qualified research associates contributed their expertise to the project. Toba Bryant is a doctoral candidate in the Faculty of Social Work in the field of health policy and housing. Wendy Regoeczi is a doctoral candidate in the Department of Sociology with expertise in the field of mental health and overcrowding. Dr. Youssef Habib is a medical doctor who has been in charge of reviewing many of the specific physical, chemical, and biological exposures. The principal investigators reviewed each section of the manuscript. A panel of advisors with expertise in housing and population health reviewed the entire manuscript. Elaboration and clarification were added where needed.

## 2.1 Health and Homelessness

In this literature review, with the concurrence of CMHC, we decided to exclude literature relating to people without housing. This was a practical decision as well as one relating to setting appropriate boundaries for this literature review.

On the practical side, there is a great deal of literature on the health issues of people who are homeless. A MEDLINE search from 1990 to July 1998, using the keywords "health" and "homeless," yielded 500 citations, including 48 review articles. The timeframe and budget of this project did not allow for this literature to be included.

In terms of setting boundaries, the health problems of people *without* housing do not logically belong in a review of literature examining the relationship between housing and population health.

It should be noted, however, that much is known about the relationship between homelessness and health. A recent editorial in the *American Journal of Public Health*, for example, provided the following summary:

> *The relationship between homelessness and health has been clearly demonstrated in numerous studies over the past decade. Homelessness is injurious to people's health and the situations in which homeless people are often compelled to live may be as hazardous to their health as the streets themselves. Homeless people are at increased risk for tuberculosis and other respiratory diseases, trauma, major mental illnesses, alcoholism and its sequelae, drug abuse and dependence, sexually transmitted diseases, and a host of other relatively minor, but nonetheless impairing, respiratory, dermatological, vascular, nutritional, and psychiatric disorders. What is more, the sick and disabled are often those who become homeless. Homelessness should be recognized as a major public health concern.*

The editorial, entitled "It's time for the Public Health Community to Declare War on Homelessness," noted the need for further applied research and that housing is only one of the fundamental requirements for health lives.

> *Public health advocates should press for the problem to be attacked from both the individual and the structural vantage points. Methods must be developed, based on risk-factor research..., to identify individuals at special risk of homelessness and implement preventive interventions. But, in addition, it must be asserted that housing, income support, education and employment are fundamental requirements for healthy lives. Political resources must be mobilized to address these issues just as vigorously as they have in the past campaigned for good nutrition, clean water, and eradication of epidemic diseases.*

People without housing, therefore, face many threats to health and well-being that people who are housed do not face.

There is also a great deal of knowledge about the population groups that are at high risk of becoming homeless. In 1997 the *Annals of Internal Medicine*, for example published a review entitled "Homelessness: Care, Prevention, and Public Policy," which provided the following summary.

Subgroups of persons who live in poverty run a particularly high risk for becoming homeless. These subgroups include persons with mental disability or post-traumatic stress syndrome associated with war service, persons who have been victimized (especially through domestic violence), persons with drug and alcohol addiction or health problems, and persons who lack sufficient social support to tide them over during potentially long periods of crisis. Other persons at risk are those who are least able to obtain jobs that pay enough to allow them to purchase or rent housing (such as single women with young children and unskilled workers) or those who do not qualify for welfare.

Addressing the health problems of people without housing is made difficult by the very fact they are unhoused.

The feasibility of creating health care services, particularly services focused on treating hypertension and tuberculosis, in places where the homeless congregate is well established. The progressive morbidity and mortality from infection, cancer, and heart disease in homeless persons could be reduced by developing primary care systems that include a common medical record across shelter sites and that offer targeted case management that focuses on influenza and pneumococcal immunization, cancer detection, and reduction of risk factors for premature heart disease. Increasing the availability of adequate low-income housing and violence prevention programs and improving alcohol and drug treatment programs could potentially reduce the risk for death from homicide and the morbidity and mortality associated with cirrhosis, injuries, and drug overdose.

The term "homelessness" itself presents difficulties. It is a fluid and confusing label for a set of social problems. It involves socioeconomic arrangements that exist quite apart from those troubled by them. It is a confusing term due to conceptual imprecision, fuzzy boundaries, the influence of political agendas, the heterogeneity of the homeless population, and the assumptions and attitudes of the housed population.

There is a similar difficulty with the term "the homeless." Different authors include different groups. The individuals or families who are labelled "the homeless" generally include people who are in one or more of the following situations in terms of their housing status:

1. people living and sleeping on the street;
2. people sleeping in emergency shelters;
3. people living in transitional housing;
4. people forced to doubled up temporarily with others to avoid living on the streets or in shelters;
5. people in serious risk of losing their current housing;
6. people in inadequate (unsafe, unhealthy) housing.

This literature review includes the last three groups because they are among the population that is currently housed. Studies on the relationship between housing and health will likely include these three groups because they are living in conventional housing.

# 3. Conceptual Framework: The Housing /Health Relationship

This chapter identifies a number of key issues and concepts relevant to making progress in understanding the housing/health relationship. It then proposes a conceptual model of the housing/health relationship.

## 3.1. Key Issues and Concepts

### What is "Health"?

Before we can discuss housing and health, we need to define health. The formal definition that is most commonly cited is one contained in the World Health Organization (WHO) charter as "a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity" (World Health Organization, 1984). This implies that health is a positive state and that it can have several dimensions: physical, mental, and social. Others have more recently added another dimension, sometimes called "spiritual." Health and Welfare Canada (1986) has explicitly recognized that health outcomes are affected by factors outside the health care sector and emphasized the social determinants of health, such as poverty and unemployment, poor housing, and other social and economic inequalities.

The WHO's holistic, positive interpretation of health was not reflected in the literature we reviewed. Almost without exception, the articles we located in our literature review were focused on the occurrence of disease or illness. Consequently, this literature review reports on the connection between housing and ill-health, not on the relationship between housing and health. As Mackenbach and his colleagues (1994:1273) suggest, "It is obvious that our understanding of the determinants of ill-health is better than that of the determinants of excellent health, and further study of the latter is recommended."

### What is "Housing"?

"Housing" should not be taken as a simple or obvious physical artefact, as simply a place where harmful things to health can be found and mitigated (Despres, 1991; Hareven, 1991; Harris & Pratt, 1993; Madigan, Munro, & Smith, 1990; Munro & Smith, 1989; Pugh, 1990; Rybczynski, 1986; Sommerville, 1992; Veness, 1992). "Housing" includes four elements, each of which plays an important role in the quality of life and overall well-being of individuals and households:

1. the house – the physical structure, its design and characteristics;
2. the home – the social and psychological aspects of the house;
3. the neighbourhood – the immediate physical area around the house and home;
4. the community – the social characteristics and range of important services in a neighbourhood.

Literature on the housing/health relationship rarely makes these distinctions. Most of the literature refers to aspects of the physical house. Some socio-psychological literature deals with the home and community, though literature measuring their impact on health is limited (and difficult).

## The Unit of Analysis

In housing research the basic unit of analysis is the household: one or more people living together in an individual dwelling. In health research, the unit of analysis is the individual. "Population health" research adds yet a different unit of analysis: an aggregate of individuals who do not live together but are defined as a group for research purposes.

Research examining the relationship between housing and health, or housing and population health, mixes two "units of analysis." This may not be significant, because the household or "population group" consists of individuals. But it may indeed be significant. Individuals who live in particular types of households, particular types of housing, or in particular locations, may have their health jointly affected in a similar way. This would occur either because of the impact of housing and the neighbourhood on health (all occupants are exposed to, for example, lead or radon), or because of the impact of health on housing (for example, the head of the household has a health condition affecting the choice and location of the place the household lives).

## The Two-way Relationship

Analysis of the relationship between health and housing must begin by recognizing that it is a two-way relationship. Housing affects health and health affects housing. Most research on the topic is focused on the former and, it seems, this may well be the primary direction of the relationship.

In her paper discussing both directions in the housing/health relationship, Smith (1990) sums up the issue with two questions. How does housing affect health? How does health status affect housing attainment? In the latter case, research needs to focus on identifying the mechanisms that sort households according to health status into different parts of the housing stock, thereby affecting access to a wide range of employment opportunities, services, and resources that are also unevenly distributed throughout the city. Kellett (1989) refers to this as the "drift hypothesis": people move into poor housing which in turn may further harm their health. But do they do so because of some pre-existing health condition or do they do so because they are poor? Both reasons seem to be valid and both have the same result – poor people live in poor quality housing and/or unhealthy neighbourhoods.

Where housing is allocated purely on a market basis, rather than, for example, on the basis of need (including medical grounds or disability status) as in social housing, people with low incomes are restricted to the bottom end of the housing market. This segment of the housing market may be cheaper precisely because of its poor physical quality or because its surroundings have environmental problems detrimental to physical and mental health.

## The Significant Role of Socioeconomic Status

One of Sociology's most enduring contributions to the health field is the documentation that social class position is a key determinant of variations in the distribution of disease. Researchers in diverse disciplines recognize that SES is so strongly linked to health that they must statistically control for it in order to study their phenomena of interest. (Williams & Collins, 1995)

In Ontario, as wealth increases, so too does health. Only 43 per cent of very poor Ontarians enjoy good to excellent health. The proportion of Ontarians reporting excellent or very good health increases to 51 per cent among the poor, 58 per cent among those with lower-middle incomes, 62 per cent among upper income earners, and 69 per cent among the wealthy. Reciprocally, 26 per cent of the very poor report fair or poor health, decreasing steadily to only 6 per cent among the wealthy. (Warren, 1994:6)

The socioeconomic status (SES) of a household plays a major role in both the health status of the individuals in a household and in the quality of their housing situation. Research has established that people with low SES in a society tend to be less healthy and to die earlier then people with a high SES. The evidence also indicates that the disparity is growing: "Despite an overall decline in death rates in the United States since 1960, poor and poorly educated people still die at higher rates than those with higher incomes or better educations, and this disparity increased between 1960 and 1986" (Pappas, Queen, Hadden, & Fisher, 1993). In their recent analysis of the evidence, McDonough, Duncan, Williams, and House (1997:1476) conclude:

> *Income level was a strong predictor of mortality, especially for persons under the age of 65 years. Persistent low income was particularly consequential for mortality. Income instability was also important among middle-income individuals. Single-year and multiyear income measures had comparable predictive power. All effects persisted after adjustment for education and initial health status.*

Further key examples of the literature on the SES and health status relationship include: Adler, Boyce, Chesney, Folkman, and Syme, 1993; Bartley, Blane, and Montgomery, 1997; Bucher and Ragland, 1995; Fein, 1995; Hay, 1988; Kaplan and Lynch, 1997; Kaplan, Pamuk, Lynch, Cohen, and Balfour, 1996; Kawachi, Kennedy, Lochner, and Prothrow-Stith, 1997; Kawachi and Kennedy, 1997; Kennedy, Kawachi, and Prothrow-Stith, 1996; Kind, Dolan, Gudex, and Williams, 1998; Roberts, 1997; Smith, Neaton, Wentworth, Stamler, and Stamler, 1996; and Wilkinson, 1996.

A recent discussion paper published by the Canadian Public Health Association (CPHA), Health Impacts of Social and Economic Conditions: Implications for Public Policy (1997), offers the following overview of the findings of the research on the SES/health relationship:

> *In virtually all societies, health status is directly related to social status. No matter the measure used, those with high incomes are usually healthier and generally live longer. Another dimension of this story can be found in the socioeconomic gradient in health. The evidence shows that a gradient exists in the rate of disease from the top of the social*

> *hierarchy to the bottom for almost every disease that has been studied, practically everywhere in the world. Higher-income people tend to live longer than lower-income people. Moreover, people on one rung live longer then those on the rung below them, on the entire socioeconomic ladder. (Canadian Public Health Association, 1997 :v)*

The CPHA paper further notes that this variation in health based on SES "is not due primarily to deprivation of food, clothing or shelter" (Canadian Public Health Association, 1997 :v, emphasis added). The paper does not address the role of housing in health and well-being, although it does refer in passing to the importance of the physical environment in general. Although the importance of SES is clear, many questions remain about the role of other factors.

Research on the housing/health relationship needs to establish the relative importance of different factors. In what ways and to what extent will certain housing (house, home, neighbourhood, community) improvements lead to improved population health? If the SES of those at the bottom of society is improved, thereby narrowing the gap between the rich and poor, will this have a greater impact on population health than, for example, retrofitting existing housing and improving the neighbourhood conditions of the poor to mitigate known health hazards?

This is obviously not an either-or option. Neither can or should be neglected. But if little is done about SES, and if SES is so important to health and well-being, including the housing one obtains in a market society, how much housing-focused attention will it take to make measurable gains in population health?

### The Role of a Nation's "Housing System"

While plenty of research has documented and debated the nuances of the relationship between wealth and health, what about the relationship between wealth (income, SES) and housing? For Canadians it does not require much research to conclude (from a drive around the neighbourhoods in any city) that poor people in a market housing system such as Canada's have poorer quality housing and neighbourhoods than wealthy people. Canada has one of the most market-oriented housing systems in the world: only 6 per cent of the nation's housing is non-market social housing (see section on Canada in Freeman, Holmans, & Whitehead, 1996). The household must have money to buy or rent adequate appropriate housing in Canada: otherwise, no money, no housing (homelessness). Some money buys "some" housing; more money buys better housing. The same is generally true for neighbourhood quality.

In addition, there is the income and housing expenditure ratio. Poor people pay a higher percentage of their income on housing for which they receive much less house (smaller, poorer quality) usually in less desirable locations. This also means that for the poor in a market system less money is left over for the other necessities of life (such as a nutritionally sound diet or the mitigation of threats to health within the home).

It is important to keep in mind that not all housing systems are like Canada's (Balchin, 1996; Clapham, 1996; Freeman, 1997; Freeman et al., 1996; Pickvance, 1986; Pickvance, 1998; Van Vliet, 1990). In the Netherlands, for example, a country with much in common with Canada in terms of culture, life style, level of development, even climate, the housing system could not be more different. A full 40 per cent of the Dutch housing stock is in the non-profit social housing sector, allocated by an administrative formula based on need (including health status) and not on the basis of income or wealth. Having little or no money in the Netherlands does not necessarily mean a household has poor quality or no housing (Balchin, 1996; Boelhouwer & Van Der Heijden, 1991; Freeman et al., 1996; Lundqvist, 1992; Priemus, 1996; Priemus, 1997).

In addition, the Netherlands has a universal shelter allowance that fills the gap between the household's ability to pay and the actual rent. The relationship between wealth and housing in the Netherlands, therefore, is very different from that in Canada. The cost of housing need not affect the rest of the household's budget as it does in Canada. To the extent that housing affects health or health affects housing, some aspects of these effects can be very different in these two countries which otherwise have a great deal in common.

A final significant difference between countries is the gap between rich and poor. In the Netherlands the gap between the bottom 20 per cent and the top 20 per cent is a factor of four (the top group has four times the income of the bottom group). In Canada the gap is a factor of 7.5, almost double. Canada's poor are much poorer relative to Canada's wealthy than is the case in the Netherlands (or in most major Western nations except the United States, Australia or New Zealand \United Nations, 1995).

These observations about structural differences in the nature of the housing systems of nations and in the extent of socioeconomic inequality point to the important role played by the broader context when we attempt to assess the housing/health relationship. Three factors are particularly important and are different in different countries:

1. the role played by market allocation versus the role played by other criteria in the distribution of the nations stock of housing resources;
2. the role played by income and wealth in obtaining not only quality housing but the other essentials of life which affect health and well-being (the nature of the "welfare state");
3. the size of the population group at the bottom in terms of income distribution (and more broadly, SES).

The degree of socioeconomic inequality produced by a particular society affects the degree of inequality in the distribution of housing resources. Aside from measuring the amount of harm that exposure to certain biological and chemical factors causes to human health, other aspects of the housing/health relationship become difficult to identify and measure precisely because of these broader institutional factors that play significant roles in housing and health outcomes.

## The Interaction Effect: The Indirect Influence of Poverty on the Health Outcomes of Household Exposures

The relationship between housing status, socioeconomic status, and health status is further complicated by interaction between SES and housing. These interactions may occur in three different ways.

The first interaction occurs through awareness. Better-educated residents are more likely to learn about and identify a risk factor. Once identified, the risk factor is more likely to be addressed. For example, those with better education are more aware of the risk factors of asbestos. They are more likely to inquire about asbestos when they select housing and identify this factor if negative health outcomes occur.

The second form of interaction effect occurs once the health risk factor has been identified. For example, once high levels of airborne asbestos fibres have been identified in a house, wealthier and better-educated residents are more likely to undergo the expensive procedure of either relocating to an asbestos-free house or having the asbestos professionally encapsulated or removed. Poorer individuals who cannot afford to remove the asbestos or obtain healthier housing will be exposed to the asbestos for a longer period of time.

We hypothesize that the first interaction (increased knowledge of risk factors among the well-educated) and the second (increased ability to minimize exposure among wealthier residents) also apply to all other housing exposures. For example, well-educated residents are more likely to know about the connection between dampness in their house and their child's asthma and have the resources to have their basement sealed to minimize dampness. Financial resources give residents freedom to select the design characteristics of the home and relocate if they are not satisfied with their housing or the indoor air quality. Overcrowding is less likely to be a mental health risk if it is due to choice rather than to financial necessity. Cold and heat risk factors are only due to poverty. Individuals with adequate funds do not need to live in a house that is too cold or too hot.

Most of the literature on housing and health does not distinguish between the outcomes for poorer versus wealthier residents. However, a third form of interaction has been found for the most thoroughly researched topic, lead.

All children exposed to lead are likely to experience a decline in IQ. However, poorer children are more likely to also suffer from poor nutrition. Children with poor nutrition absorb higher quantities of lead at every level of exposure. Therefore, poorer children are likely to experience more negative outcomes from the same level of lead exposure than are richer children with better nutrition. In this case, poverty interacts with the housing exposure (lead) to exacerbate the negative outcome. Research is needed to determine the extent to which these interaction effects exist for each of the housing factors we discuss.

### Health Status Impact on Housing Status

Wealthy individuals typically do not lose their housing status when their health deteriorates. If health status affects employment status and results in lower income, however, poorer people will need to find a new (and cheaper) living arrangement. This arrangement may be less healthy and worsen existing health problems.

Smith, Alexander, and Esterlow (1997) cite the British council housing situation where ill-health is considered a factor sufficient to qualify for a move to another, presumably better, council housing flat. Their research examines residential mobility (rehousing) as an effective health intervention, concluding the "medical rehousing is something more than a mirage, but rather less than a miracle." It is unclear whether this may play a significant role in the Canadian public housing environment.

## 3.2 A Conceptual Model of the Housing/Health Relationship

The housing/health relationship can be conceived as starting with the acknowledgement that socioeconomic status (box 1) is extremely important and is the starting point in explaining the relationship. An individual's physical and mental health status (box 2) and a household's housing status, the quality of the house and home, and the neighbourhood and community, (box 3) is affected (largely determined) by SES. There is a two-way relationship in both cases: health affects SES and SES affects health, and housing affects SES and SES affects housing.

This relationship is mediated by a number of factors. These are the objects of research on the housing/health relationship. Much research has been carried out on some aspects of the impact of housing on health. The housing factors which affect health are grouped into five general areas:

- Box 4 – chemical exposures;
- Box 5 – biological exposures;
- Box 6 – physical characteristics of the housing;
- Box 7 – social and economic characteristics of the housing; and
- Box 8 – psychological factors relating to housing.

The impact of health on housing (box 9) is an area where there is limited research thus far. This is the case of health affecting housing attainment (an issue relating to access to appropriate housing). Having HIV/AIDS, a physical mobility impairment, a serious and recurring mental health problem, being a member of a group that is subjected to housing discrimination by landlords and mortgage lenders, and so forth, means that an individual (and his or her household) has fewer and generally worse housing options to choose from. Health status as well as SES negatively affects housing access. If the nation has an almost pure market allocation process for housing access, then health status and SES are serious barriers to obtaining appropriate (and healthy) housing.

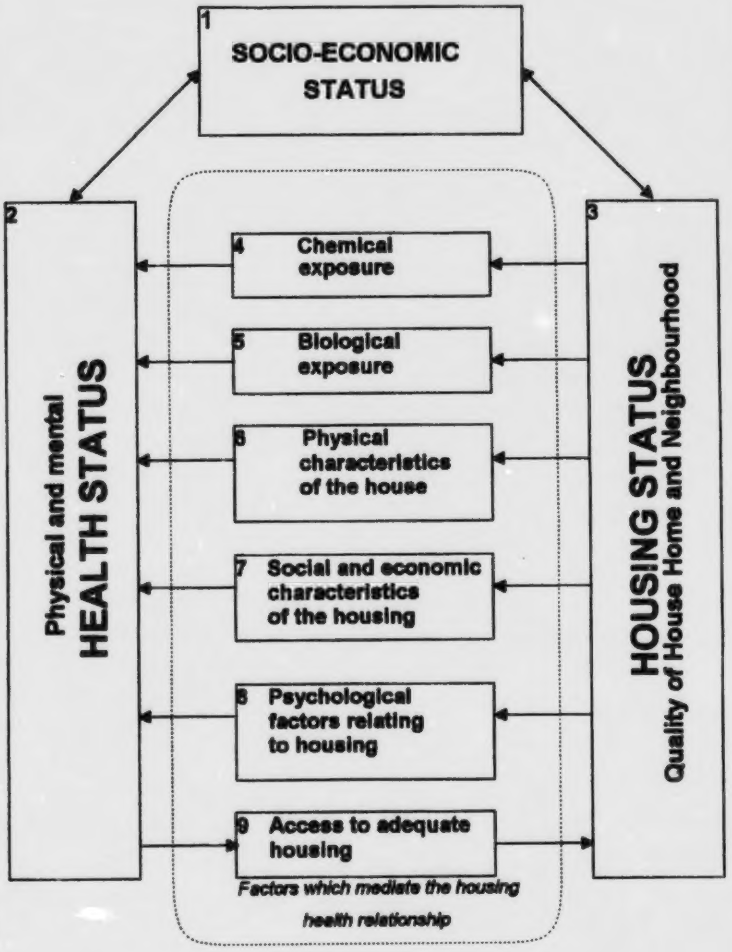
Once health status and SES affect housing attainment , in terms of getting poor-quality housing, then there is the feedback of one's poor housing status further affecting one's health status. Depending on the quality of the housing, the problems identified in boxes 4, 5,6, 7 and 8 may have a further negative impact on health.

The policy question relating to a societal desire to improve population health is: where does one achieve the greatest health improvement relative to the resources (effort, time and money) invested?

- Is it by investing in box 3: retrofitting existing houses and neighbourhoods and building new healthier housing in healthier locales?

- Is it by investing in box 2: improved medicine and health maintenance services as well as active health promotion campaigns?
- Is it by investing in box 1, improving the SES of those at the bottom, thereby reducing inequality, resulting (as all the literature seems to indicate) in better health (box 2) and better housing (box 3)?

**Fig 1: CONCEPTUAL MODEL OF THE HOUSING HEALTH RELATIONSHIP**


1
SOCIO-ECONOMIC STATUS
2
Physical and mental
HEALTH STATUS
3
HOUSING STATUS
Quality of House Home and Neighbourhood
4 Chemical exposure
5 Biological exposure
6 Physical characteristics of the house
7 Social and economic characteristics of the housing
8 Psychological factors relating to housing
9 Access to adequate housing
Factors which mediate the housing health relationship

## 4. The General "Housing and Health" Literature

Some literature, from the titles at least, would appear to directly address the housing/health relationship. Most of these publications, however, consist of either very general discussions or advocacy for an improved link between housing and health. Some of the literature reports on research findings (such as a survey of public health officials) and some offers advice on research methods and policy options (Conway, 1995; Essen, Fogelman, & Head, 1978; Hopton & Hunt, 1996; Kearns, 1995; Kearns, Smith, & Abbott, 1991b; Lowry, 1988; Lowry, 1991; Smith, Kearns, & Abbot, 1992; Warsco, 1992) World Health Organization, 1988). Some of the better examples are discussed below.

### 4.1 Significance of Housing to Health

Bequette's 1998 article on "Healthy Housing" in *The UNESCO Courier*, for example, focuses on indoor air quality and mentions a few of the better-known housing-related factors that affect population health (asbestos, parasites, lead, and smoke). Kellet's review article entitled "Health and Housing" provides a general descriptive overview of literature on mental health and housing without drawing any specific conclusions. He asserts that prevention of "disease depends just as much on our architecture as on immunisation" and that dissatisfaction with the built environment can lead to physical and psychological distress affecting health and general well-being. He notes that although there are many studies that try to measure and define the relationship between the health of people and their built environment "most are seriously flawed" (Kellett, 1989:256).

Walker's 1990 "Housing and Health" focuses on the difficulties of doing research on the topic, noting that "we tread on difficult epidemiological terrain when we attempt to develop a statistically precise analysis of the interrelationship between housing and health." Many of the most important dimensions, he notes, are not susceptible to measurement. Studies that attempt the difficult task of measurement must leave out many variables for practical reasons, must often use indirect indicators or measures, and must often ignore important variables which simply cannot be measured (Walker, 1990:383). He summarizes the problem in the following way:

> Typically, epidemiologists have available all kinds of statistical data on causative agents of disease. But epidemiology requires more than knowledge of specific organisms or other primary determinants of disease and dysfunction. It equally requires knowledge of the contributing factors or secondary determinants – the community, the psychology of its people, their social and economic position – and consideration of the possibility that they may operate independently and singly or synergistically. Thus, any exploration of housing and health issues must include a reflection of socioeconomic position – an amalgam of income, education and occupation – which can be rightly called a true generic "housing-health risk factor." (Walker, 1990:384)

Recognizing that poverty and substandard housing are related leaves open the question of whether this means more than simply that poor people live in poor housing. Walker notes that the quality of the housing itself may have "something to do with thebehavioural, economic, and psychologic syndrome we define as poverty" (Walker, 1990:384). In addition to the practical research problems, Walker argues for a breaking down of the traditional compartmentalization of disciplines and professions. Creative and collegial thinking is required to address such complex problems as housing and health (Walker, 1990:390).

Another general article, by nurses (Sargis, Jennrich, & Murray, 1987), titled "Housing Conditions and Health: A Crucial Link" restates the obvious. They add the observation about people who have received formal health care services but then must return to poor quality housing which may hamper their recovery, or worse.

It is unfortunate that individuals without life-threatening illnesses must live in housing that can cause health problems, and it is even worse that sick individuals discharged from health care facilities must return to unhealthy homes and communities. There is no question that nurses continue to have legitimate roles in analyzing home conditions that affect patients' states of being. (Sargis et al., 1987:338)

Roderick, Victor, and Connelly (1991), who conducted a survey of public health directors, recommend that the training of public health physicians and other doctors (especially general practitioners) include an understanding of housing policy and the effects of poor housing on health. There should be increased health input into training local authority housing and social services staff. They advocate the use of national data on adverse health effects of housing shortages and poor quality housing to promote a housing policy that emphasises the public health. A critical component of a healthy housing policy would be to establish health standards for house building.

Schaefer's (1990) article "Home and Health – On Solid Foundations," although still very general, is a very helpful introduction. It is based on a World Health Organization survey confirming that a large part of humanity lacks adequate shelter or even the knowledge of how to obtain health benefits from housing. Of the 70 countries surveyed, only 23 had adequate housing for at least 75 per cent of their population. Conditions were not improving, or were even deteriorating in at least 20 counties. People in the major Western nations – where most people have adequate and safe housing – tend to take for granted the important basics that adequate housing contributes to health.

Schaefer notes, citing WHO's 1987 report, *Housing – the Implications for Health*, that the relationship between housing conditions and health are known and have been codified. Schaefer identifies four categories:

- *protection against communicable diseases*: an adequate and safe water supply, proper disposal of solid wastes, facilities for personal and domestic hygiene and sanitary food preparation, and structural safety against disease transmission, which includes adequate interior space;
- *protection against injury, poisoning and chronic disease*: safe furnishings and structural features, control of indoor air pollution, safe handling of chemicals, and adequate facilities where the home is used as a workplace;

- *minimal exposure to psychological and social stress:* suitable living space, family ties to the community, proper siting, access to safe play and recreation, minimal exposure to excessive noise, and as few personal hazards as possible;
- *provision of adequate neighbourhood services*: the necessary physical infrastructure, security and emergency services, access to educational, health and social services, and access to cultural and other amenities (Schaefer, 1990:38).

In addition to these benefits, it is also important to recognize that the manner in which people use housing can profoundly influence its health potential. Children, for example, must be protected from numerous items and situations that are not a health or safety hazard for adults.

When most of the population have obtained these basic housing requirements important to health, as they have in countries like Canada, it becomes an increasingly sophisticated scientific task to identify the more subtle relationships between housing and population health. Yet few countries put adequate resources into this endeavour. Schaefer (1990:44) reports that the provision of specialized staff to deal with the health aspects of housing "is pitifully meagre in most countries" and where health ministries have units concerned with housing matters, they are given "low status and priority in comparison with medical programme units." He continues:

> *This neglect constitutes a major shortfall in public health leadership. Epidemiologically, it means ignoring the relationships between housing, host resistance, protection against the biological, chemical and physical agents of disease, and medical interventions, both preventative and curative. Socially such neglect weakens those elements of primary care that link health with living conditions, community participation, and socioeconomic development. (Schaefer, 1990:44)*

Is housing a public health issue? Roderick, Victor, and Connelly (1991) asked directors of public health about the importance of housing for public health and about their departments' and health authorities' participation in housing issues. A self-administered postal questionnaire survey was sent to all 221 district health authorities in England and health boards in Wales, Scotland, and Northern Ireland, with a response rate of 89 per cent. They found the following: housing was perceived as a major health problem by 33 per cent of directors; positive responses were most likely from inner-city districts; 53 per cent of directors had included housing issues in their annual health report; and specific services for the homeless had been set up in 16 per cent of the districts. The authors concluded that most of the housing-related activity related to mandated functions (such as allocation of medical priority for public housing) rather than health promotion activities relating to housing:

Although concern about the impact of current housing policy on public health was shown by a substantial number of directors, the main activity was still allocation of medical priority despite a background of increasing housing need and homelessness. The underlying need is for greater advocacy to produce a healthy housing policy for all, and the annual public health report could be used to promote this objective.

Smith, McGuckin, and Walker (1994) add to this general discussion of the relationship between public health and housing by focusing on housing management. Theirpaper examines the character and effectiveness of the British approach to "healthy alliances" between health professionals and housing managers, and considers its future prospects.

## 4.2 What Can be Done?

The general literature on health and housing often mentions policy options for improving population health by focusing on housing and neighbourhood quality. Schaefer (1990) provides one of the better summary lists.

- *Health advocacy*: make health considerations integral to public and private decision-making about housing.
- *Influencing economic and social policies*: housing improvements often depend on policies for which the primary responsibility lies outside the health sector, such as socioeconomic development, basic infrastructure, land tenure, local government powers, rights of landlords and tenants, family planning, and land use regulation.
- *Participating in and managing processes of planning, policy implementation and service provision*: health authorities should promote health values in the planning and management of socioeconomic development, urban land use planning, the development and enforcement of housing legislation and standards, and the provision of community services.
- *Public and professional education*: decisions about housing and behaviours governing its use can be influenced through the use of education of: the occupants, architects, builders and manufacturers, health workers, and local and national policy makers.
- *Fostering community organization and participation*. In the promotion of self-help and community co-operation, education should lead to group action for the improvement of dwellings and neighbourhoods. (Schaefer, 1990:43-4)

On this last point there is some literature about individual and community empowerment among disenfranchised groups in society. Elliott Brown et al. (1998), for example, outline a case study of an empowerment approach to developing culturally appropriate neighbourhood-based health promotion in a low-income neighbourhood. Their focus is on the process used and the extent to which it can inspire community health-enhancing change. The process has potential for replication, if not the exact program components. In their case study they identified five strengths of the community-based health promotion model: the empowerment process itself, shared ownership, community-based location, relationship with a university, and community partnerships.

In similar fashion Chavis and Florin (1990), in an article entitled "Nurturing grassroots initiatives for health and housing," argues that health promotion and the need for adequate housing can be addressed through grass-roots community development. Community organizations have been shown to be effective in the social, physical, and economic development of a community. Policy makers and strategists can improve the effectiveness of such organizations by developing a system to support community initiatives by developing structure, functions, and services as part of an enabling system.

By way of conclusion, Schaefer (1990) notes that if "health ministries are to engage in such actions to promote the health aspects of housing, they require explicit policies and priorities, organized and timely information, linkage to sources of expertise, adequate numbers of competent personnel, and mechanisms of co-ordination with mainstream health care services. This means, however, that it is vital to have clear, realistic standards that are epidemiologically sound and affordable for the populations concerned.

# 5. Specific Physical or Chemical Exposures

## 5.1 Lead

Lead is the main environmental toxin affecting children living in deficient housing. Although children are particularly vulnerable to lead poisoning, occupational sources pose a risk factor for adults. There are numerous sources of lead in the environment such as lead paint chips and dust from walls and older toys and contaminated soil from industrial sites, deteriorating external paint, and leaded gasoline emissions. Lead paint and leaded gasoline are no longer used, but there is still contamination from these sources. Lead poisoning is associated with a decline in children's IQ, anemia, and damage to the nervous system.

### Sources of Lead

There are two major sources of lead in households: lead paint and contaminated soil. The most important source of high-dose, concentrated lead exposure is lead paint that has deteriorated into paint chips and lead dust (Mahaffey, 1983 as cited in Landrigan, 1990a). Before 1970, the lead content of paint was 50 per cent lead by dry weight, reduced now to 0.06 per cent (600 parts per million) for interior and exterior residential surfaces, toys, and furniture (Schneitzer, Osborn, Bierman, Mezey, & Kaul, 1990). In a study performed by Schwartz and Levin between 1976 and 1980 in Chicago, paint lead exposure was a highly significant factor in predicting lead toxicity. Using regression models to eliminate the effect of leaded gasoline, lead toxicity could only be attributed to paint lead. In a recent study conducted by Lanphear et al. (1996), lead-contaminated house dust was found to be a significant source of lead intake in urban children who have low-level blood lead elevations.

Immediate risk of exposure to lead depends on whether the lead-painted surfaces are intact or deteriorated, and on the dust lead levels. Lead dust is a critical indicator of risk. It is ingested during hand-to-mouth activity of children and is a major contributor to the total body burden of lead in young children. Paint abatement may generate significant amounts of lead-containing dust and fumes that may be ingested or inhaled by young children (Rabinowitz et al., 1985 as cited in Landrigan, 1990a). Refinishing activity in homes with lead paint was associated with elevations of blood lead levels of 69 per cent.

The age, type, and condition of housing proved to be significant in a study done by Chisolm et al. (1985). A group of preschool children with high pre-treatment blood lead received in-patient chelation therapy to treat their elevated blood lead levels. They were then followed for 12 to 30 months as outpatients. There was a significant difference in blood lead levels in children discharged to old houses in which lead paint had been abated and those discharged to lead-free housing. In the former group 50 per cent had one or more recurrences of elevated blood lead levels.

In another study by Clark et al. (1985), the highest blood lead values were highly correlated with the condition and the age of the children's housing. They were highest in children living in houses built before the 1950s in deteriorated condition, and lowest in children living in recently built houses. In a paper examining data from 200,000 children inChicago screened over a five-year period, Schwartz and Levin (1991) also found that lead paint exposure was a highly significant factor in predicting toxicity.

Soil is another significant source of lead exposure. The Centers for Disease Control (CDC) in Atlanta, Georgia reported in 1991 that flaking and weathering of leaded paint on houses contributes to the lead content of urban dust and soil. In addition, lead in soil comes from many sources such as lead-based paint removal by sanding, leaded gasoline emissions, industrial emissions, and other emissions that have accumulated in the environment. Mielke et al. (1997) found a strong association between low soil lead levels and communities with new housing. The association between the age of housing and soil lead concentration was strongest in large cities. Marcus and Cohen (1989, cited in Schwartz & Levin, 1991) suggested that each 1000 ppm of lead in the soil contributes 2 µg/dl to blood lead. In their study, Weitzman et al. (1993) concluded that lead-contaminated soil contributes to the lead burden of urban children. However, the magnitude of reduction in blood lead levels indicates that lead-contaminated soil abatement is not likely to be a useful clinical intervention for the majority of urban children with low-level lead exposure.

A study by Al-Radady et al. (1993) of leaded windows as a source of lead inside houses found that lead levels on the interior surfaces was significantly greater than the levels on the exterior surfaces. This is especially true when lead is used as binding strips or channels, referred to as cames, which hold together pieces of stained glass in window panels. Very high lead concentrations were collected from the sills of leaded windows. This could be attributed to corrosion of the cames and dissolution by window condensate.

According to the Centers for Disease Control report, other sources of exposure for adults and children includes lead dust brought into the home on clothing from workplaces, lead used for some hobbies, and lead in plumbing, crystal, and ceramic containers. However, leaded paint remains the most significant source of contamination.

## Health Effects of Lead Exposure

Lead poisoning and its effect on the nervous system in children was first described in Australia in 1897. Shortly after, the association with lead paint as the main source of exposure was found, and lead was banned from interior house paint in Australia in the early 20th century.

Lead exposure in young children is a particular hazard because children absorb lead more readily than adults do. During the childhood years, the nervous system is more susceptible to the effects of lead. Blood lead levels as low as 10 µg/dl can have an adverse effect on behaviour and development. Levels of 15 to 40 µg/dl cause irreversible deficits in intelligence, behaviour, and school performance. No treatment can replace nervous tissue destroyed be chronic lead absorption, or lost intelligence (Landrigan, 1990b). Once in the brain, lead levels remain elevated even after the return of blood lead levels to non-dangerous levels (Goldstein, 1992).

Considering the number of children suffering from lead toxicity, it is considered one of the most common childhood diseases (Falk and Ing, 1989 as cited in Schwartz & Levin, 1991). Blood lead levels which were previously considered safe are now associated with many adverse health effects especially in children. It is manifested mainly as IQ deficits and neurobehavioral disorders (Mushak & Crocetti, 1989). Elevated lead leads to a 4.5 pointmean deficit in verbal IQ in kids. This shift in mean IQ scores results in trebling in numbers with IQs below 70 (Needleman et al., 1979 as cited in Landrigan, 1990a). In another study Needleman and Gatsonis (1990) and Schwartz (1994, cited in Lanphear et al., 1996) found a 2- to 3-point deficit in IQ for each 10 µg/dl increase in blood lead. These deficits are irreversible.

Children could also be affected before birth. Children exposed to lead in utero were found to have lower IQ scores. This effect was correlated with lead levels in umbilical cord blood at birth, even for levels as low as 15 to 20 µg/dl. (Landrigan, 1990 and Bellinger et al., 1987 cited in Schneitzer et al., 1990). These findings indicate that there may not be a safe blood lead level for children.

Effects on the nervous system have also been recognized in adults (Valciukas et al., 1980 as cited in Schneitzer et al., 1990). In adults, lead toxicity usually manifests as wrist or ankle drop caused by damage of the peripheral nerves and paralysis of the extensor muscles of hands and feet. These symptoms usually occur at high doses

Anemia is the most serious effect of lead toxicity on the blood, because lead increases red cell destruction. The effect on blood becomes manifest at blood lead levels of 15 to 20 µg/dl (Hammond, 1985 cited in Landrigan, 1990a). This is compounded by the presence of iron deficiency, a common phenomenon in inadequately housed children. An increase in blood lead is highly correlated with iron deficiency ( Mahaffey and Annest 1986 as cited in Crocetti, Mushak, & Schwartz, 1990; Mahaffey and Michaelson, 1980 quoted from Landrigan, 1990a).

Epidemiological and clinical studies confirmed the toxicity of lead in children at levels that were considered safe a decade ago. Lead causes subclinical poisoning, in which blood cells, kidneys, reproductive organs, and, most importantly, the nervous system of young children are affected. All of these effects occur in children who have no clinical symptoms of lead poisoning (Landrigan, 1990a). There is a small difference between the population mean blood level and the levels at which health effects are seen (Schwartz & Levin, 1991). In 1991 the CDC published the revised guidelines for preventing lead poisoning. The critical blood lead level was decreased by 60 per cent (from 25 µg/dl to 10 µg/dl). A blood lead level of greater than 19 µg/dl is recommended for routine environmental intervention.

## Factors Contributing to Lead Toxicity

Age is a significant contributing factor to lead toxicity because lead is ingested in the normal hand-to-mouth activity of toddlers. Mushak and Crocetti (1989 as cited in Goldstein, 1992) detected a peak in blood levels at the age of 18 months. Other factors contributing to the toxicity in this age group is the relative ease with which lead is absorbed in children's digestive systems, and also the pattern of developmental changes and maturation in brain tissue at this age.

Iron deficiency, poor nutritional status, low calcium intake, and immaturity are all risk factors associated with enhanced absorption and retention of ingested lead (Mahaffey, 1990 as cited in

Goldstein, 1992). The absorption of lead is markedly increased when it is ingested in the absence of food, because particulate lead dust is highly soluble in the acid environment of the stomach (Chisolm, 1986).

In their study examining data from 200,000 children in Chicago screened over a five-year period, Schwartz and Levin (1991) found that the relative risk of lead toxicity givenlead exposure was 5.7 during the winter and fall, 12.8 in the spring, and 15.8 in the summer. They ascribed the higher odds of lead toxicity in summer to increased exposure to window wells. The greater humidity in warm weather may also result in more peeling of lead paint and hence increased exposure.

In major urban cities the greatest lead hazards are found in areas where poverty is greatest (Goodman, Shultz, Klitzman, Kimmelblatt, & Spadaro, 1993). In a report from the CDC's National Health and Nutrition Examination Survey, conducted between 1991 and 1994, living in an urban area was not an independent predictor of elevated blood lead when controlling for race/ethnicity, income, and age of housing.

Crocetti et al. (1990) emphasized the cumulative risk for the exposed population. They pointed out that the cumulative effect over extended time is of greater magnitude than the prevalence or total exposure at a point in time for a given year.

## Prevention of Lead Exposure

Short-term controls include restoring surfaces to an intact condition, and long-term permanent abatement focusing on hazardous lead paint on walls. Friction and impact points on windows and doors are of particular concern.

It is also recommended that, when possible, professional deleaders should perform the restoration and renovation of older homes and buildings that contain lead paint,. Dust generated by this work is hazardous for occupants, especially for children. Researchers recommend that during the abatement or renovation process, children, pregnant women, and women of child-bearing age should not be present (Amitai, Brown, Graef, & Cosgrove, 1991; Schneitzer et al., 1990). Adequate masks and ventilation should be provided (Schneitzer et al., 1990). Bates et al. (1997) found that high temperature methods for lead paint removal posed the greatest hazard. Propane torches, hot air guns, dry scraping, or sanding should not be used in removal of lead paint. A wet chemical process for paint removal would be safer and is suggested by Farfel and Chisolm (1990). It retains the residues, hence allowing for proper disposal. This process also does not leave behind lead particles that may increase lead levels in dust. After the work is finished, the surfaces should be washed with a detergent that binds lead.

Chelation therapy is conducted on children with high blood lead levels. The therapy binds lead and promotes its excretion from the body. However, if children return to high lead environments after the therapy, they are particularly vulnerable due to enhanced intestinal absorption of lead (Goldstein, 1992).

Boiling water for at least one minute reduces lead concentration in water (Haschke, Steffan, Schilling, Schuster, & Salzer, 1985). Boiling for ten minutes almost completely removes the lead from water. This finding is of particular importance for parents preparing infant formula.

## 5.2 Radon

Radon is an alpha-emitting radioactive gas that emerges from the soil and enters homes primarily through openings or cracks in the building foundation or through well water. Ambient radon gas and its particulate progeny result in respiratory exposure toalpha emissions. According to the available scientific evidence, inhalation of radon gas, especially in high doses, can cause lung cancer. The current dispute is in relation to the effects of lower radon concentrations, as found in most of the residential settings. The publication of the report of the Committee on the Biological Effects of Ionizing Radiation, BEIR VI (1990), of the National Research Council, suggest that results of case-control studies have generally been based on extrapolation from data on underground uranium miners, under past conditions of exposure. Neither the study population nor their working conditions are likely to be representative of the general population (American Medical Association Council on Scientific Affairs, 1991).

The extent to which radon may be carcinogenic in the residential environment has not yet been established through direct epidemiological research. Enough evidence has not been provided to rule out the possibility of risk through residential exposure, although at present, the evidence cannot relate residential exposure to radon gas to the development of lung cancer (Neuberger, 1992).

The risk of exposure to radon and its decay (daughter) products, and hence the increasing risk of developing lung cancer, was found primarily in studies of underground miners and in animal studies (Archer, 1988). The risk of lung cancer in miners exposed to high doses is significantly increased in smokers (Moolgavkar, Luebeck, Krewski, & et al., 1993; Whittemore & McMillan, 1983). This risk is estimated to be 10 times higher than in non-smokers (National Research Council (United States) Committee on the Biological Effects of Ionizing Radiations, 1988). Most of these studies did not control for smoking, which is itself the major risk factor for the development of lung cancer, both in males and females. Most studies also did not address confounding from exposure to other carcinogens in the mines. There is also scepticism about the quantitative assessment of exposure and calculation of the dose of radon (Brill et al., 1994). Current radon measurements are taken as a surrogate for the historic exposures of cases and controls. Unexpectedly, Cohen (Cohen, 1990) reported a significant negative correlation between radon levels and lung cancer rates.

To minimize flaws in the methodology of studies of effects of residential exposure to radon on health, Létourneau et al. (1994) recommended adjusting for smoking habits and other confounding factors such as education, country of birth, and occupational factors, when estimating odds ratios for lung cancer and radon.

### Sources of Radon in Homes

Most radon in the atmosphere is not from radon but from the short-lived alpha-emitting radon daughters. Radon is a daughter product of radium, which in turn is a radioactive decay product of uranium. Radon in homes comes primarily from soil. Rock permeability is an important factor influencing radon availability on the surface. Another potential source of exposure is outgassing from high radon levels in water. This exposure occurs mainly from rural household wells. Municipal water supplies are aerated, which decreases radon levels (Brill et al., 1994). When water use is high, outgassing from water leads to increased air levels of radon (Pritchard & Gesell, 1981). Flowing and heated water release dissolved radon into the home atmosphere causing an elevation in air levels in homes. Radon levels are dependent on the radon content of water and the amount used daily. Seventy percent of the water content of radon is released into indoor air (Bruno, 1983). Indoor radon levels are also affected by occupancy. Radon concentration was found to increase three- to fivefold when apartments were occupied (Pritchard & Gesell, 1981).

Radon in the soil is under higher pressure than in the air inside the house. Therefore, radon flows from the soil into the house. Radon enters a building in several ways and once inside, the concentration of the particulate progeny tends to increase with the continuous decay of radon. Indoor levels are two to three times higher than outdoor levels. The weaker the barrier between the soil and the interior, the higher the level of radon in the house. Concrete is more permeable to radon than other building materials. Houses with dirt floors in basements or crawl space are particularly vulnerable (Brill et al., 1994). Radon can also enter a house through ground-level drainage systems or through defects in concrete in floors or in walls (Tanner, 1988).

Since the main source of radon for a house is soil, radon concentration in a house tends to be highest in basements and becomes insignificant at upper levels. Létourneau et al. (1994) found that radon levels in other floors of the house were two thirds of those measured in the basement. Radon levels are higher in winter, when the area surrounding the house is frozen. Upon freezing, soil permeability is diminished. However, there is warmer soil under the house foundation, which makes it easier for the radon to permeate into the house. The lack of adequate ventilation in winter months and deposition of radon daughters on the heating ducts and filters also contribute to the elevation of radon levels in indoor air during winter (American Medical Association Council on Scientific Affairs, 1991; Letourneau, Zielinski, Krewski, & McGregor, 1992; McGregor, Walker, & Letourneau, 1985; Perrit et al., 1990; Tanner, 1988; Ulbak et al., 1988).

## Significance of Radon and Its Relation to Health

The magnitude of the risk to radon exposure is related to the intensity and duration of exposure. A house with windows and doors that are kept closed most of the time has higher radon levels. Also, a home that is unoccupied most of the day presents fewer hazards to residents than one where people are indoors most of the time. The linear no-threshold model is the most appropriate one for estimating lung cancer risk from exposure to radon (American Medical Association Council on Scientific Affairs, 1991).

Exposure to radon can only be detected through measurement. There are no warning symptoms. In a review of the 15 largest ecological studies of residential radon and its contribution to the risk of developing lung cancer, Stidley and Samet (1993) could not find any inference to the understanding of the quantitative effects of indoor radon.

A large-scale case-control study was conducted in Winnipeg, Manitoba, by Létourneau et al. (1994) between 1983 and 1990. Their study included 738 case-control pairs matched by age and sex. Winnipeg was chosen because it has the highest levels of indoor radon among 18 other Canadian cities reviewed previously by McGregor et al. (1980). Radon was monitored in as many of the homes occupied by study subjects as possible. After considering confounding factors, such as cigarette smoking and education, the authors found no increase in the relative risk of radon exposure and any of the different types of lung cancers. Compared with cigarette smoking, exposure to radon is a much less significant hazard, especially in the range of residential exposure levels (American Medical Association Council on Scientific Affairs, 1991).

### Prevention of Elevated Indoor Levels of Radon

Levels of radon in the range of 148-296 Bq/m$^3$ do not warrant mitigation. The Canadian national guideline is 800 Bq/m$^3$ (Krewski, Miller, Eaton, & et al., 1989). Mossman and Sollitto (1991) conducted a cost-benefit analysis of mitigation of radon in homes in the United States. They suggested that any regulation to achieve levels below the national standards of radon in homes would not be cost-effective except in the case of homes with high radon levels. The latter account for less than 10 per cent of the total domestic radon risk.

In areas with high levels of radon in water supplies, water purification systems may have a significant effect on reduction of exposure. On the other hand air purification systems have not been found to be sufficient (Brill et al., 1994).

Opening windows could help when high levels of indoor radon need to be abated. Simple rotating household fans could reduce indoor levels by as much as 40 to 60 per cent, especially if used during winter months when lack of ventilation contributes to the elevation of ambient radon levels (Maher, Rudnick, & Moeller, 1987; National Council on Radiation Protection and Measurements, 1989).

Covering exposed earth reduces the inflow of radon, as does sealing cracks and defective openings in basements, low-level walls, and floors (Brill et al., 1994).

## 5.3 Asbestos

Asbestos is a generic term that covers two kinds of fibrous silicates: the serpentine, mainly chrysotile ("white asbestos"), which has a more flexible texture, and the amphiboles, mainly amosite ("brown asbestos") and crocidolite ("blue asbestos"). The fibres are regarded as being equally toxic to the pulmonary epithelium and to the immune response. The most serious carcinogenic potential for mesothelioma and bronchogenic carcinoma comes from crocidolite and other amphiboles (Committee on Environmental Hazards of the American Academy of Pediatrics, 1987 as cited in Angle, 1988). Currently the majority of white asbestos is used in asbestos cement products and in friction materials(Raw & Prior, 1993). Alternative non-asbestos fibre reinforced materials are now available (Health and Safety Executive, 1986 as cited in Raw & Prior, 1993).

Asbestos is a good example of an environmental hazard magnified by low-level universal exposure starting at a young age (Angle, 1988). Deriving a risk model from the occurrence of mesothelioma in insulation workers gives grounds for expecting a growth that is exponentially related to the years from the time of first exposure or time raised to a power of 3.2 (Doll and Peto, 1985 as cited in Angle, 1988). There is also some evidence suggesting heightened exposure among household contacts of asbestos workers compared to others merely living in the area (McDonald, 1985). Causal evidence exists in relations of asbestos to asbestosis, respiratory tract cancers, malignant mesothelioma, tumours, and gastrointestinal tract cancers, at least in occupational studies (McDonald, 1985). However, according to the World Health Organization (1987, cited in Raw & Prior, 1993), exposure to very low levels of airborne fibres typically found in buildings poses an extremely low risk of lung cancer — estimated to be between one in 100,000 and one in a million. Although the noncombustible fibrous particles are of greatest concern, there are also growing indications of the fibrogenic potential of the glass fibres and mineral wools (Angle, 1988).

There are several reasons why the health effects of asbestos are difficult to determine (McDonald, 1985). First, asbestos consists of several materials, each having different chemical, physical, and biological qualities, and possibly different health effects. Second, dimensions, durability, respirability, retention, and surface reactivity have substantial biological pertinence, and in different situations, there may be tremendous variation in the same mineral. Finally, it is important to consider the interaction between asbestos exposure and cigarette smoking when assessing the risk of respiratory tract cancer. Unidentified elements may also be implicated in the cancers of the gastrointestinal tract.

Although asbestos is a proven human carcinogen, the domestic risk of exposure is estimated in dwellings which, for the most part, have much lower concentrations than those involved in the initial demonstration of the carcinogenic potential of asbestos (Mant, 1993). Thunhurst (1993) notes that classical statistical methods, which place the burden of proof on disproving a null hypothesis, may be too conservative for the detection of health hazards like asbestos. He argues that the unavoidably small samples used when investigating specific hazards to asbestos workers means that reaching statistical significance will only occur when the health impacts are severe.

## 5.4 Electromagnetic Fields

Electromagnetic fields (EMF) are generated by the flow of electricity through wiring. Exposure to elevated EMF in the household setting usually occurs when homes are located close to high-current electrical power lines. The potential health effect of EMF has been the subject of extensive debate since the initial report of an association between EMF and childhood cancer mortality by Wertheimer and Leeper in 1979. Subsequent research has focused on four possible health impacts of EMF: (1) childhood cancers, (2) adult cancers, (3) pregnancy outcomes, and (4) psychological effects. The results of these studies have been contradictory, with some finding an association between EMF andillness, and others no association. Relatively small sample size and methodological difficulties in assessing exposure to EMF have limited many of these studies.

A comprehensive review of the literature by the National Research Council (1996) has determined that currently available scientific evidence neither proves nor disproves that EMF has any adverse effects on health. When a proxy for EMF is used, based on wire codes or wire configuration near the house, studies indicate that there are 50 per cent higher odds of childhood leukemia. However, studies using direct measurements of residential magnetic fields have not demonstrated an association between EMF and cancer.

## Childhood Cancer

The effect of EMF on childhood cancers has been the subject of intensive scrutiny. We reviewed 23 studies which have had the greatest impact on the question of EMF exposure and its effect on health. One of these studies (Wertheimer & Leeper, 1980) found a higher-than-expected incidence of childhood cancer. The same authors later found an association with both childhood and adult cancers (Wertheimer & Leeper, 1982). Both of these studies considered wire coding or configuration as the only measurement of exposure to EMF. They did not attempt to measure the actual magnitude of exposure, and the assignment of homes was not conducted in a blind manner with respect to cases and controls. Tomenius (1986) also found higher odds for childhood central nervous system (CNS) tumours, but not for leukemia. Their description of the methodology was incomplete, which affects the reliability of their study. The authors did not indicate that their study was conducted in a blind manner. The three previous studies also did not investigate the possible confounding effects of other factors, which might influence the outcome of exposure to EMF.

Four other studies did not find any association between EMF exposure and malignancies. Fulton et al. (1980), using the same wire coding principle of Wertheimer and Leeper (1980; 1982), found no association with childhood leukemia. Myers et al. (1985) found a weak association that was not statistically significant. Savitz et al. (1988) and Severson et al. (1988) did not consider confounding in their study designs, but they could not find any correlation between exposure and development of childhood leukemia.

In a meta-analysis of well-designed studies in this area, Washburn et al. (1994) identified 13 studies,that examined EMF and its effect on health. Six of these studies found an increased relative risk (RR) for leukemia, and although statistically significant, none of these studies controlled for confounding variables. Five studies found a relationship between EMF exposure and lymphoma, however, these studies did not reach the level of significance. Seven studies found a statistically significant increased risk of CNS tumours.

Using criteria for wire coding (especially the highest wire-code category), Linet et al. (1997) conducted a case-control study on 638 children and 620 controls. Adjusting for potentially confounding variables, they also did not find any relationship between time-weighted average residential magnetic field levels and leukemia. A significant dose-response effect has not been observed in their study, even after adjusting for socioeconomic, demographic, or other potentially confounding variables. The authors could not exclude the possibility of a small increase in risk among children in homes withvery high magnetic field levels, as suggested in other studies (Tomenius, 1986) (Feychting & Ahlbom, 1993; Verkasalo et al., 1993).

Concerning the quality and quantity of the available evidence, most of the studies cannot determine the nature nor the magnitude of the risk with certainty. A limitation of all studies to date is the absence of measurements for individual homes in the years preceding the diagnosis of cancer (Linet et al., 1997). This adds to the consensus of the multitude of studies discussing this issue, that there no biophysical mechanism through which EMF could be responsible for the development of cancer (Michaelson, 1991).

### Adult Cancer

Nine epidemiological studies reviewed the risk of cancer among adults exposed to residential EMF. Overall, findings from these studies are inconsistent. One study reported an overall increased risk of leukemia (Coleman, Bell, Taylor, & Primic-Zakelj, 1989). Wertheimer and Leeper (1982) reported an association with CNS tumours. The flaws in the methodology have been discussed in the previous section. The relative risk for leukemia associated with residential magnetic field exposure $\geq 0.2\ \mu T$ was found by Feychting et al. (1997) to be 1.3; however, among those subjects experiencing high exposure at both home and work, the relative risk increased to 3.7. In two cohort studies McDowall (1986) and Schreiber et al. (1993) found no evidence for a positive association. The remaining publications could not find a correlation with increased health risks (Feychting & Ahlborn, 1994; Youngson, Claydon, & Myers, 1991) Severson et al., 1978). In a review of epidemiological studies, Li et al. (1996) could not relate residential exposure to magnetic fields and cancers among adults. They found no dose-response relation. This is mainly due to the studies' small sample sizes and concomitant inadequate statistical power.

### Pregnancy Outcomes

The effect of EMF exposure on pregnancy has been raised by Wertheimer and Leeper (1986; 1989) and Juutilainen (1993). In a case-control study of the effects of residential exposure to extremely low frequency (ELF) magnetic fields, Juutilainen et al. (1993) used early pregnancy loss (EPL) as a sensitive indicator of embryonic hazards. After taking into consideration the confounding effects of maternal age, smoking, and type of dwelling, strong magnetic fields were found more in cases than in controls. However, the small study size and large dropout rate make their conclusions imprecise.

Savitz and Ananth (1994) examined data from a large study of childhood cancer in Denver (Savitz et al., 1988). They could find no relationship between magnetic field and pregnancy loss, low birth weight, or preterm delivery. Their study provides weak evidence of a relationship between exposure to magnetic fields and adverse pregnancy outcomes due to the absence of data on other risk factors, bias in self-reporting by study subjects, and the small sample size extracted from the original data set (which had other goals in the original study design).

### Psychological Effects

Six studies have been reviewed to detect a correlation between homes near high-current power-transmission lines and adverse behavioural effects. Dowson and Lewith (1988), Perry et al. (1989), and Poole et al. (1993) found an association with depression. This has been disputed by McMahan et al. (1994), who found no correlation with depression. Perry et al. (1981) found an association with suicide.

To test the validity of previously published research work while controlling for potential confounders, Beale et al. (1997) conducted a cross-sectional study of the dose-response relationship within a population living in proximity to transmission lines. Interviews included the administration of five tests of attention skills, two tests of memory for new material, and three questionnaires. Taking the Digit-Symbol test (a subset of WAIS-R Intelligence Test) as one of the most sensitive indicators of brain damage, they found a significant dose-response relationship between time-integrated exposure, rather than average exposure, and some psychological symptoms, such as anxiety and depression.

The available evidence from several epidemiological studies and reviews could not correlate exposure to electric and magnetic fields and human-health hazard. Although some epidemiological data support a relationship between wire coding and distribution as a proxy measurement of magnetic field and increased risk of childhood leukemia, these are considered at best indirect estimates of the magnitude of exposure (National Research Council (United States) Committee on the Possible Effects of Electromagnetic Fields on Biologic Systems, 1996).

## 5.5 Urea Formaldehyde Foam Insulation (UFFI)

Urea Formaldehyde Foam Insulation (UFFI) is material used for insulation. Formaldehyde is released into the home during the initial installation and shortly thereafter. To a lesser extent, formaldehyde is also released over time as the polymer decomposes (Norman & Newhouse, 1986). Research has investigated links between UFFI and a variety of health problems. Studies have examined such health conditions as symptoms of the upper and lower respiratory tract and gastrointestinal tract, asthma and chronic bronchitis, dermatitis, psychological symptoms (such as insomnia and depression), nasal cancer, and lymphoma (Harris et al., 1981, Schenker et al., 1982, Infante et al., 1981, Nantel et al., 1982, as cited in Norman & Newhouse, 1986). The primary sources of UFFI are insulation, particle board, carpeting, and gas appliances, all of which are located inside the home (Norman & Newhouse, 1986).

There is currently no consensus in the scientific research community on whether a causal link between UFFI and various health problems exists (Norman & Newhouse, 1986). UFFI is made up of polymers of urea and formaldehyde which are combined with a variety of other chemicals (Norman & Newhouse, 1986). Therefore it is difficult to isolate the health effects of UFFI from other potential chemicals with which it may be combined. In addition, much of the research to date has been cross-sectional surveys which are unable to show causation. Although it is easy to establish the date the UFFI was installed,many studies use subjective assessments such as retrospective recall to assess when symptoms began. Such assessments are often inaccurate.

Of the literature reviewed, five studies investigated the presence of a causal association between UFFI exposure and the incidence of chronic respiratory problems. Three of the five studies reported a relation. There was a large range of UFFI exposure in the home environment reported in these studies (between 0.054 and 0.46 ppm). Two studies reported significantly higher prevalence rates for asthma and chronic bronchitis in children and non-specific symptoms. Bracken et al. (1985) reported significantly increased prevalence of nasal symptoms, headaches, and throat irritation in the UFFI-exposed subjects in a case-control study. Using a cross-sectional survey of 298 children, Krzyzanowski et al. (1990) reported significantly higher prevalence rates of asthma and chronic bronchitis in children from houses with indoor formaldehyde levels of 60 to 120 ppb than in children from less exposed homes. Children who are exposed to environmental tobacco smoke seemed to be particularly vulnerable. In another cross-sectional survey of 1000 people, Liu et al. (1991) suggested synergistic effects between formaldehyde exposure and chronic health problems. Irritant effects were detected and associated with formaldehyde exposure after controlling for age, sex, smoking, and chronic illnesses.

In contrast, Norman et al.'s (1986) case-control study reported no evidence of respiratory problems from UFFI exposure. Their study detected no significant differences in respiratory function in children living in homes insulated with UFFI (n=29) compared with controls (n=58). They report that the study had sufficient power to detect important changes. Two other studies (Broder, Corey, Brasher, Lipa, & Cole, 1991; Vaughan, Strader, Davis, & Daling, 1986) suggest that the association between UFFI and health conditions such as specific cancers (pharynx, sinus, and nasal) and selected chronic health problems (nasal problems, eye irritation, fatigue, cough, sputum) may be due to factors other than formaldehyde exposure. Using a sample of 443 mobile homes, Norsted et al. (1985) found no evidence of a dose-response relationship in a survey of homes built between 1979 and 1981 in which they monitored the homes for UFFI levels. The study investigated only mobile homes for which occupants had registered complaints with the local health department.

Most of these studies were case-control designs and some were cross-sectional designs. The case-control design is considered a stronger design for establishing causation than cross-sectional studies in which both the exposure and outcome are collected at the same time. Norman and Newhouse (1986) argue, however, that the onset of symptoms is not well established in any of the adequate studies which claim to have found an association. In addition, most studies rely upon respondents' memories, which are subject to bias. The three studies examined in this review that found an association used cross-sectional surveys relied on the recall of symptoms by respondents, sometimes verified by physician diagnosis. However, most studies that found an association used independent measures of UFFI levels to verify the reports of respondents.

None of the studies could explain the mechanism by which the health effect occurred. In addition, the sample sizes in these studies were inadequate for establishing causation. Liu et al. (1991) had a sample of 298 children. Norsted et al. (1985) had a sample of 443.

# 6. Specific Biological Exposures

## 6.1 Damp and Mould

Most of the studies in the literature on damp housing examined the association between the presence of damp and mould in the home and the incidence of respiratory conditions such as asthma in children and adults. Peat, Dickerson, and Li provide a recent review of the literature on the effects of damp and mould in the home on respiratory health. It is believed that the links between respiratory illness and mould are mediated by allergies to fungi in subjects. These allergies are usually confirmed by skin tests. The levels of various indoor fungal allergens are usually independently verified. These studies have several methodological problems that make it difficult to establish causation.

Young children are considered to be particularly vulnerable to respiratory ailments as a result of the amount of time they spend in the home. Women and the elderly are also at risk. Increasingly, however, studies are examining the potential links between damp and mould and adverse health effects in adults. Poverty may be a confounding variable. Poorer individuals are more likely to be ill. Substandard housing is generally less expensive and therefore more likely financially accessible to poorer individuals. The damp and mould may, in turn, exacerbate pre-existing health conditions. It is often difficult to determine when a health problem began. A difficulty found in several of the studies is that of isolating the impact of current damp housing on health from the effects of previous exposures. It is difficult to assess the effects of mould exposure independently of other factors because skin reactions to mould extracts are generally related to skin hypersensitivity to pollen or house dust mites .

**Dampness, Moulds, and Respiratory Illness in Children**

Numerous studies have been carried out on the respiratory infections and other conditions in children who live in damp housing. These studies are usually cross-sectional surveys in which parents are invited to report on the presence of respiratory conditions, such as wheezing or persistent coughing, in their children. Subjective and objective measures of dampness and mould in the homes are usually taken to control for bias.

Strachan et al. found a highly significant association between mould and wheezing in a study of 1,000 children aged six and seven. Respiratory symptoms were assessed through parental reports and medical exams. A week-long continuous measurement of temperature and relative humidity of the bedrooms of one-third of the respondents supplemented parental reports of dampness and mould. The study also examined for the presence of specific moulds. Higher levels of mould were found in the homes of children with a wheeze. The association was found to be largely independent of other social and housing variables. The study seems to suggest an allergy to fungi that may spore. The authors conclude that the causal link between respiratory disease and damp, mouldy housing should be based on valid and objective measurements. Strachan et al. failed to explain how this link might be made.

A case-control study by Lindfors et al. found that dampness in the home increased the risk of asthma among children one to four years of age exposed to environmental tobacco smoke. In a large cross-sectional survey of children aged 12 to 14, coughing was found to be associated with damp . However, although the effects are significant, they are not very strong, with relative risks lower than 2.

On the basis of a cross-sectional survey of primary school children in the subtropical rural areas of the Kaohsiung region of Taiwan, Yang et al. found significantly more frequent symptoms of coughing, wheezing, bronchitis, and asthma in damp homes than in dry homes. These relationships held after adjustments for potential confounding factors.

Some studies have investigated the effects of indoor temperatures and humidity. In a cohort design, Ross et al. investigated a potential association between domestic temperatures and humidity and upper respiratory tract infection in children. They obtained objective measurements of domestic temperature and humidity in the bedrooms of a large random sample of 297 children aged 24 to 59 months with and without respiratory tract conditions over a six-day period. A research assistant interviewed the parents on the age and type of house and the length of stay; forms of cooking and heating used in the home; methods of ventilation; room occupation, sleeping habits and conditions, as well as smoking habits of the occupants; employment status and social class. In addition upper respiratory tract infections were recorded retrospectively over the previous 12 months as well as during the study period. No significant differences were detected in the mean conditions between children with infections and those without infections . Nor was an association found between environmental factors and reported "usual cough," asthma attacks, or bronchitis. Differences between the two groups of children were small. Ross et al. report that the children who wheezed tended to have gas fires rather than central heaters; and wheezers slept in bedrooms that tended to be cooler (t180=1.89, p=0.060). They suggest that although the difference was small (mean difference=0.9°C), cooler bedroom temperatures may contribute to wheezing in children.

Ross et al. sought linkages with conditions that were insufficiently defined. Also, there were potential sources of bias with respect to under- or over-reporting of health conditions by parents.

Using a triple blind procedure, Hunt et al. found a significant dose-response relationship between aches and pains, wheezing, vomiting, headaches, sore throat, irritability, fever, poor appetite, coughing, and runny nose and dampness among children in three Scottish cities. A significant dose-response relationship emerged in relation to the amount of visible mould and wheezing, sore throat, irritability, headaches, fever, and runny nose. A dose-response relationship between air spores and wheezing, fever, and irritability also emerged. When controlling for other relevant factors affecting symptoms, significant associations remained between dampness/mould and wheezing, sore throat, headaches, and fever.

Su et al. carried out a cross-sectional survey of 150 school-aged children to measure the potential associations among airborne fungi that can be cultured. The survey included questions about the child's health, including the presence of hay fever, wheezing condition and/or asthma, and lower respiratory illness, such as bronchitis, a persistent cough, or chest illness keeping the child at home for three days or more. The study population was recruited from 350 homes that were used for biological testing for the presence of decay fungi. Factor analysis was used to select subsets of 14 microbiological variables to explain the relationships from "difficult-to-interpret" correlated variables with a small number of conceptually meaningful, relatively independent factors. Overall correlation coefficients were reported as small but statistically significant. Six factors explained 64 per cent of the variance. Wheezing and/or asthma and hay fever were significantly associated with factor 1. Only three fungi were identified in this association Cladosporium, Epicoccum, Aureobasidium and yeast spp ($p=0.03$). These are classified as outdoor fungi that grow on aboveground dead organic material. No other significant associations were observed.

The methodology and design were sound. However, it is not clear how the association is mediated. They suggest, but do not explore, the possibility of "cross-reactivity between allergens" which may mediate this association.

In a case-control study, Verhoeff et al. investigated the association between home dampness and the respiratory symptoms of children. They collected house-dust samples from bedroom floors and mattresses in 60 homes in the Netherlands to check for the presence of fungal propagules. They used a checklist and questionnaire to obtain information on home characteristics and resident behaviour. The children's homes were divided into four groups: 1) homes of children without reported respiratory symptoms (controls) and without observed dampness; 2) homes of children with respiratory symptoms, but observed dampness anywhere inside; 3) homes of children with reported respiratory symptoms (chronic wheezing, chronic coughing, attacks of shortness of breath with wheezing, or physician-diagnosed asthma) as cases without observed dampness; and 4) homes of children with respiratory symptoms and observed signs of dampness. Bivariate and multivariate linear regression analyses were carried out to investigate the association between numbers of colony forming units (CFU/g) of dust and home characteristics.

Verhoeff et al. found that dust counts from textile flooring was four times higher than samples from smooth floors, and was also statistically significant ($p<0.001$). Higher numbers in mattress dust were associated with observed mould growth and damp patches in the bedroom, and lower numbers were linked to the presence of furniture placed directly against an outer wall. Only a weak relation was found between home characteristics and the number of fungal propagules in floor and mattress and dust. Finally, no differences were observed between the presence of fungal propagules in house dust of cases with reported respiratory symptoms and those of controls.

Verhoeff et al. raise more doubts than they are able to address. They suggest that given the large number of statistical comparisons carried out, the two significant relationships may have been caused by chance. The total CFU/g for mattress and floor dust were not associated with the average relative indoor humidity measured over six weeks. Although they used objective instruments to measure actual dust levels in homes, they were unable to explain a potential causal link, and once again attribute the difficulties to the use of a symptom checklist. Only Su et al. investigated a potential correlation among the fungi. They also found an association between wheezing and asthma and hay fever.

In these studies, allergy to the identified fungi was not explored as a potential mechanism through which an health effect might occur. Also, the sample sizes may have been inadequate for detecting a statistically significant result.

### Dampness, Moulds, and Respiratory Illness in Adults

The attention to respiratory conditions in adults as a result of home dampness and mould has been of more recent interest. A Canadian study by Dales et al. examined the association between dampness and moulds and symptoms among adults in a cross-sectional survey of 14,799 adults from across Canada. The participation rate was 83.2 per cent. They controlled for sociodemographic variables of age, gender, race (white or other), maximum parental education, household crowding, region, and occupation. They also recorded the incidence of smoking, the use of wood or gas stoves for cooking, as well as hobbies, pets, the use of portable gas or kerosene heaters or fireplace to heat, and the presence of forced-air heating.

Logistical regression analysis showed an association between lower respiratory symptoms and dampness and mould adjusted for smoking status (O.R.=1.74, 95 per cent CI: 1.60 to 1.90). Odds ratios were calculated for persistent coughing (1.82), persistent phlegm (1.87), wheezing (1.68), and wheezing with dyspnea (1.86). Symptom prevalences were reported to increase with increased numbers of mould sites. Also, the association between dampness and symptoms held in those without indicators of atopy.

They also stratified the data by smoking status, and found that the prevalence of all symptoms was about 150 per cent higher in damp homes . Dales et al. also identified a dose-response gradient between the number of mould sites in the home and all symptoms, but not diagnosed chronic respiratory disease or asthma.

The authors also acknowledge over-reporting and under-reporting by respondents, and the fact that symptomatic subjects may be more likely to report the presence of dampness and moulds to explain their health problems as potential sources of bias. They controlled for over-reporting and under-reporting biases by inviting respondents to report any other major illnesses (such as headaches, muscle aches, fever and chills, nausea, vomiting, diarrhea) or accidents in the previous three months. Respondents who tended to over-report were expected to respond affirmatively more often to this question than those who under-reported. For the second bias, they argue that respondents would need to know that respiratory symptoms are related to the presence of home dampness or moulds. It remains unclear, however, how the relationship between respiratory conditions and the presence of dampness and mould is mediated.

A study by Iversen and Dahl that used a retrospective cohort design more clearly demonstrates how an association between asthma and damp housing might occur. The study population consisted of 326 patients with a prior clinical diagnosis of bronchial asthma who were referred for allergological evaluation. Each patient received a skin prick test for the mite allergy and common inhalation allergens (birch, timothy, mugwort, cat, dog, and horse). The researchers assessed housing conditions by questionnaire with special emphasis on questions to indicate damp housing conditions, such as the presence of visible mould in the present or former dwelling of subjects. They measured high indoor humidity during the winter by the presence of water condensation on the inside of double-glazed windows. Standardized sampling and analysis of dust from mattresses measured mite exposure in homes. Using contingency tables, the study identified damp housing conditions as mediating the dust mite allergy in asthmatic patients. The study, however, did not have a control group, and may not have controlled for a large range of potential confounders.

Using a cross-sectional survey design, Pirhonen et al. investigated the prevalence of mould problems in 1,521 homes and their potential association with respiratory diseases and symptoms among a randomly selected adult population living in the subarctic climate of Eastern Finland. The questionnaire queried the presence of visible dampness and mould growth using four definitions of damp and mould: 1) visible mould stains on the walls or structure of the home; 2) mould odour; 3) moisture stains or visible mould or mouldy odour; and 4) water/moisture damage or moisture stains or visible mould or odour of mould. The participation rate was 76 per cent.

After adjusting for atopy, the study found that bronchitis, rhinitis, fever and chills, hoarseness, and fatigue were all significant in houses with visible mould stains. They detected no differences in the prevalence of wheezing and difficulty in breathing between residents in homes with or without mould. They concluded that the prevalence of mould in homes was related to the definition used. However, using different definitions did not seem to alter the pattern of symptoms or respiratory diseases associated with exposure to damp or mould in homes.

The lack of objective measures of mould problems or respiratory infections, as the investigators admit in their discussion, raises concerns about the validity of their damp and mould measures. They controlled for "complainer" respondents by creating a variable that captured negative effect. The use of an expert walk-through inspection for dampness and mould in the home together with self-reports could have provided a check on self-reports of dampness and mould in the home. This study appears to have been among the first to investigate an association between respiratory conditions and damp in a subarctic culture.

Williamson et al. investigated damp housing and asthma in a case-control study. The study population consisted of 102 subjects aged 5 to 44 years with physician-diagnosed asthma, who attend a hospital asthma clinic and 196 age- and sex-matched controls. There were two controls for each asthmatic patient in the study. Of the cases and controls, 222 (75 per cent) consented to an independent home inspection for dampness. The purpose of the study was to establish whether subjects with physician-diagnosed asthma were more likely than age- and sex-matched controls to live in damp housing, and to determine whether living in such conditions adversely influences the severity of asthma. Subjects were blind to the purpose of the study.

Using a structured interview, a trained researcher asked participants about housing conditions, particularly the presence of current dampness or condensation in the home and exposure to dampness and mould in previous dwellings, and about the presence, frequency and severity of wheezing, chest tightness, coughing, and shortness of breath on exercise. Current asthma medications and number of exacerbations of asthma that required oral steroids in the previous year were also recorded. The study detected a strong association between the presence of dampness and mould within a dwelling. Of the independently surveyed homes, 49 (86 per cent) showed evidence of visible mould growth and areas of detectable dampness. The correlation between total mould and total dampness scores of a home was significant and explained 26 per cent of the variance.

Through self-reports and independent evaluations of home dampness, the investigators found a tendency for both case and control subjects to under-report the dampness in their homes . Dampness was detected in the homes of 21 (52 per cent) of the asthmatic and 27 (32 per cent) of the control subjects who claimed their homes were dry. There was agreement between self-reported dampness and surveyor findings in 83 homes (63 per cent) of control subjects and 56 (63 per cent) of asthmatic subjects. They also detected the tendency of both measures of dampness or mould to rise with increasing severity of asthma. The correlation between asthma severity and total dampness scores was significant and positive explaining about 9 per cent of the variance. There was also a significant correlation between asthma severity and total mould scores explaining about 5 per cent of the variance. There were no significant differences in the mean indoor relative humidity levels either in case or control homes.

The study is reasonably sound in establishing a link between dampness and mould in the home and asthma and other respiratory conditions. The case-control design is strong for evaluating associations between exposures and outcomes. Also, cases clearly were diagnosed with asthma since they were recruited from a hospital asthma clinic. Controls were matched on two potential confounders. Subjects were not told about the purpose of the study. The home inspectors were not told the health status of subjects. It is not clear from the findings that dampness and mould are causes of asthma; nor is it clear how the relationship is mediated. It is not clear whether cases and controls all lived in Greater Glasgow, an urban centre where people are exposed to a wide range of environmental conditions that could also affect respiratory conditions.

Another study by Beaumont et al. examined the presence of fungal air spores inside and outside the homes of eight asthmatic, mould-sensitive patients in the Netherlands. They also sought to investigate a potential association between the occurrence of fungal spores and the course of the patients' obstructive lung disease. All patients had partially reversible chronic airflow obstruction, and ranged in age from 16 to 69 years. Beaumont et al. describe the design as "sequential sampling" of fungal air spores. They recorded quantitative and qualitative variations in mould-spore concentrations in the environments of the patients. Using an Andersen sampler, they monitored the homes aerobiologically, including the living room, bedroom, and kitchen, and obtained a fourth sample from a potentially mouldy place such as cellar or scullery. They also measured the patients' lung function by peak flow (PF) rate, as well as monitoring the clinical condition of each patient during the study. They devised clinical criteria for rating an increase in pulmonary complaints: 1) a subjective increase in bronchial obstructive complaints with a decrease in PF values of more than 15 per cent; 2) increased cough with expectoration and a rise in measures suggesting an exacerbation of allergic bronchopulmonary aspergillosis.

Penicillium was found to be dominant in seven of the eight environments, but did not appear to have seasonal associations . Cladosporium was second to Penicillium as a dominant fungus in four homes and third in two homes with the highest concentrations occurring between May and September. Other frequent moulds were Botrytis, yeasts, and Aspergillus. They were unable to demonstrate that the fungi induced increased pulmonary complaints.
Again, it seems clear that the difficulty of studies that aim to show a causal link between the presence of fungi in the home and asthma is explaining how the effect occurs. The external validity of the study is doubtful given the small sample size.

### Dampness and Emotional Distress

One study found that an aspect of poor housing that was significantly and independently associated with greater emotional distress was reporting a problem with dampness . This study ranks among those cross-sectional studies that are higher in quality, was based on an adequate sample size, and the results were moderately strong. Furthermore, the authors controlled for sociodemographic and economic variables identified as being significantly related to the dependent variable. However, this study was cross-sectional and therefore, causation cannot be assumed.

This literature tends to use cross-sectional surveys to show an association between dampness and a particular health condition. One weakness is related to self-reporting as a data source which can introduce bias. Respondents were volunteers who may not be representative of non-respondents. These studies as a whole cannot explain how symptoms occur, whether there is an interaction with other variables, or whether damp and mould exacerbate pre-existing health conditions.

### Policy Advice on Damp and Mould Problems in the Home

What are the potential benefits compared to the costs of reducing damp and mould in existing houses? In their review of the literature, Peat, Dickerson, and Li note that this question has not been sufficiently investigated. They do offer the following policy advice based on the literature: The potential benefits of reducing mould in the home have not been investigated, and the few studies that have investigated health improvements as a result of increasing ventilation or reducing damp in order to reduce house-dust mite levels suggest that this intervention is expensive, requires a large commitment, and is unlikely to be successful in the long term. This implies that houses need to be specifically designed for primary prevention of respiratory problems associated with indoor allergen proliferation rather than using post hoc procedures to improve indoor climate and reduce allergen load as a secondary or tertiary preventive strategy .

## 6.2 Dust Mites

House dust mites (HDM) are microscopic organisms that thrive in a habitat characterized by a temperature of 17-25°C and humidity greater than 50 per cent. There are three main house dust mites: *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, and *Dermatophagoides microcerus*. The one most implicated in HDM discussions is *D. pteronyssinus*, which produces the *Der p* I allergen. In 1989 Platts-Mills and De Weck estimated prevalence of HDM allergy to be 45 to 85 per cent in asthmatic patients and 5 to 50 per cent in controls. As measured at baseline and one year later in two large population-based surveys, mite allergens tend to show stable concentrations, especially if no extermination efforts were carried out .

HDMs cause allergic manifestations in humans, typically manifesting as bronchial asthma, allergic rhinitis, and atopic dermatitis. People with high levels of HDMs in their homes have five times greater risk of having atopic dermatitis . In a WHO workshop, the overall threshold level of sensitization was found to be >= 2000 ng mites/gram of dust. Levels at or above 10,000 ng/gram of dust increases the risk of asthma attacks in individuals already sensitized . It was even found in a prospective study that exposure to high levels of dust mites during the first year of life might predispose exposed infants to the development of atopic disease later in life . It was estimated that

50 per cent of atopic cases (as defined by an increase in Immunoglobulin E "IgE" levels), and 20 per cent of controls were sensitized to HDM. Both cases and controls were more likely to live in humid surroundings .

HDMs require suitable nesting sites such as upholstered furniture, textile floor coverings, bedding, and stuffed animals. They also feed on human skin scale . In a study done by the Department of Dermatology and Venerology in Odense University Hospital in Denmark, Beck and Bjerring found that the mite population in homes depends on production of dandruff. Their study was designed to measure the concentration of HDM in dust of mattresses from bedrooms of non-atopic individuals who had psoriasis. This was also congruent with a previous study done by the same authors on atopic dermatitis patients (both are scaly skin diseases).

Mite allergen tend to be concentrated in mattresses. They are then shed and are transferred to the floor. This has been suggested by higher levels of *Der p* I in mattress dust both in bedrooms with smooth floors and those with carpeted floors . In high altitudes and during dry seasons, such as in winter, populations of HDMs tend to decrease Spieksma, 1997). In a cold temperate climate, the type of building construction and ventilation seem to influence the existence of HDM allergen in homes.

In a cross-sectional survey, Wickman et al. found that houses with both natural ventilation and crawl-space basements had lower mite allergen levels in mattresses than houses with the same type of ventilation, but with a concrete slab basement. They also detected seasonal fluctuations in levels of HDMs and their allergen, as they tend to increase in summer and decrease in winter. Spieksma found that level of humidity in winter is a determinant factor for the prevalence of dust mites throughout the year. Extermination of mites during the dry winter season leaves insufficient time for mites to re-establish themselves during the short duration of the more humid summer. Levels of HDM allergen are directly related to indoor humidity. In their survey to detect increased risk of asthma attacks in sensitized individuals, Wickman et al. measured allergen levels in dust samples from box-spring beds and foam mattresses together with the absolute indoor humidity (AIH). They considered a history of water vapour condensation on the inside of double-glazed windows in bedrooms or in living rooms as an sign of high AIH and poor ventilation in winter. They found that HDMs thrive in a warm and constantly humid environment such as that typically found in beds and mattresses. They could not find an association between box-spring beds and increased growth of mites, compared with polyether foam mattresses. In other studies, absolute humidity (measured as gram of water vapour per kilogram of air) was considered more suitable for climatic and physical measurement, whereas relative indoor humidity, as a comparison to external humidity, was best suited for studies of habitats of mites. Relative humidity is highly temperature-dependent .

In a case-control study, van Strien et al. studied the relationship between humidity and respiratory symptoms in children. They measured levels of *Der p* I in floor dust and mattress dust in 516 homes in the Netherlands. *Der p* I level in carpet dust was 6 to 14 times higher than that from floors with smooth coverings. Dust from smooth floors with rugs had 4 to 7 times more *Der p* I than that from smooth floors. They also found a positive correlation with the age of the house and of the floor covering, number of occupants, and absence of floor insulation. *Der p* I level in dust from mattresses and carpeted floors was positively associated with relative humidity in bedrooms. Homes with natural ventilation had higher levels of mite allergen than those with continuous mechanical ventilation.

Although mattress dust or dust from carpets has been used as the major source of HDM allergen in most of the research studies, Price et al. , refuted this assumption when they found in a cross-sectional study that air sampling was a more accurate measure of exposure to mite allergen. In this study there was no correlation between *Der p* I level in carpets and that in the air. On the other hand, airborne allergen at detectable levels was highly associated with sensitivity to mites. They found significantly higher levels of airborne *Der p* I in homes with wool carpets compared to those with synthetic carpets, although levels in carpet-dust did not differ by any significant level. In another cross-sectional survey carried out in two Canadian cities with different climates, Vancouver and Winnipeg, Chan-Yeung et al. measured mite allergen levels in the dwellings of 120 asthmatic patients. The aim of their study was to detect the effect of season, city, indoor relative humidity, and home characteristics on allergen levels. They found certain home characteristics favoured the proliferation of HDMs and hence increased levels of their allergens. They suggested that the type and age of the house, type of heating, use of feather pillows, and the number of occupants are positively correlated with levels of *Der p* I in house dust. Mean indoor relative humidity in Vancouver was significantly higher than in Winnipeg in each season. In multivariate analyses, allergen levels differed significantly from home to home, but were significantly higher in Vancouver than in Winnipeg for all seasons. Floor allergen levels were positively associated with the number of occupants, in both cities.

A case-control study of patients with mite-sensitive asthma included 14 patients who moved to mechanically ventilated homes, which were considered "healthy." Eleven patients who remained in same dwelling formed the control group. Harving, Korsgaard, and Dahl obtained an initial evaluation of lung function, symptoms, and medication requirements before moving and after five and fifteen months. They found statistically significant improvement in Forced Expiratory Volume in one second ($FEV_1$), indicating a decreased obstruction to air flow out of the lungs (the main pathologic dysfunction in asthma resulting from bronchial hyperreactivity), medication requirement, and serum IgE (which is increased in allergic and atopic states). The most important and distinguishing feature of new healthy homes was the mechanical ventilation system providing dry conditions, which are adverse for the growth of dust mites. This mechanical ventilation has also been found to be beneficial in decreasing indoor humidity in several other studies . On the other hand, forced air heating was found to increase mite allergen levels. This has been attributed to air being loaded with dust, which is a feature of this type of heating systems .

Trying to find efficient and cost-effective methods for combating the proliferation of HDMs, Colloff, Taylor, and Merretts found that steam cleaning of carpets and furniture is the only method of HDM control combining elimination of the mites and significant reduction of their allergens. They observed that moisture has not been retained for a prolonged period of time, which provides an unfavourable environment for mites to re-establish themselves after cleaning, as is the case in wet vacuuming.

To decrease or mitigate most of the allergic manifestations of HDMs, several procedures have been suggested. Efforts to eliminate HDMs should be focused on the bedroom. Mattresses and box springs should be encase in dust-impermeable or plastic covers, and zippers should be covered with tape. Casings should be vacuumed more than once a week. Washable polyester pillows are better than feather ones, otherwise the latter should be zippered in tight plastic casings .

Humidity reduction is the most effective method. Newer building constructions should be equipped with mechanical exhaust and supply ventilation systems to reduce indoor relative humidity. Basement construction should not promote dampness . Healthy indoor environments with adequate fresh air ventilation were also proposed as a way to manage mite-sensitive asthma . Heating bedrooms decreases relative humidity, which depends on ambient temperature in the house . Also, removal of heavily infested objects and mattresses is an effective measure, as vacuum cleaning is not very helpful in reducing the allergen load . More frequent replacement of mattresses and floor covers will also reduce allergen exposure .

Colloff, Taylor, and Merrett have suggested temperature treatment of potentially infested objects. Heating to at least 50°C, and preferably 97.9°C to 121.3°C under wet conditions usually rids the object of both the mite and its allergen. This steam cleaning is most suitable for carpets and furniture.

Chemical control could be used but mites tend to proliferate after treatment. S-bioallethrin 0.293 per cent w/w and Bioallethrin 0.585 per cent was developed in France and was reported to be beneficial in a study conducted in Britain by Stephenson in 1991. This acaricide is used to spray the room, which is then vacuumed.

Allergic patients should be advised against living in the lower levels of buildings, and to avoid damp homes. Homes with underfloor heating should be given preference .

Based on their study of residents from a group of flats in Bucharest, Chirila et al. conclude that situations supporting the cultivation of fungi and mites within the housing microclimate constitute the primary factor initiating respiratory syndromes, in particular allergic bronchial asthma.

## 6.3 Cockroaches

Cockroach antigens are proteins found in insects' saliva, excreta, eggs, and shed cuticles. These antigens are implicated as one of the major causes of asthma among inner-city children. After being airborne, they are inhaled and induce the formation of antibodies. They persist in uninhabited locations for prolonged periods of time, usually exceeding five years, even after the eradication of cockroaches . Textile floor coverings favour the presence of higher levels of cockroach allergen .

There are about 15 to 20 protein antigens. These are produced by several types of cockroaches, including American, German, and Asian varieties. German cockroaches live only in locations inhabited by people. This variety of antigens should be taken into consideration when using detection probes, as it is easy to miss most of them when using monoclonal antibodies to detect a single cockroach antigen.

Allergy to cockroach antigens causes respiratory symptoms in children, which most commonly manifests as asthma. One or more allergens usually trigger asthma. This implies that an antigen might be detected by testing, but this antigen might not cause asthma. Allergic manifestations usually persist even after fumigating homes with pesticides, hence indicating that this method of abatement does not alleviate the physical manifestations of allergy . In 1997 Wijnen et al. conducted a pilot study in which subjects were recruited from a previous case-control study of respiratory symptoms and home dampness. They measured specific IgE antibodies against cockroach allergens in 96 children from the latter study. Cockroach allergens were detected in dust from 44 per cent of 46 houses with recent cockroach extermination. Four (16 per cent) of children with respiratory symptoms and 4 per cent of the group without respiratory symptoms had elevated specific IgE to cockroach.

On the other hand it was found that common household cleaners decrease antigen levels by 90 per cent. Second cleaning adequately eliminates antigens and virtually reduces their levels to zero . It has been suggested for a long time that exposure to cockroach allergen may cause asthma. In a recent longitudinal study, Rosenstreich et al. found a positive correlation between allergy to cockroach antigens and exposure to high levels of these antigens, and morbidity in inner-city children suffering from asthma. In this study, patients were divided into four groups according to their allergies and the levels of allergen in bedrooms. Group 1 included those not allergic and with low bedroom levels of allergens, group 2; those who were not allergic but whose bedrooms had high allergen levels, group 3; those who were allergic and had low allergen levels; and group 4, those who were both allergic and had high allergen levels in their bedrooms. Bedroom dust samples were analysed for house dust mite allergen, cat allergen, and cockroach allergens. Half of the bedrooms had high levels of cockroach allergen, compared with 12.6 per cent with high levels of cat allergen, and 9.7 per cent with high levels of dust mite allergen. They found a higher correlation between asthma morbidity and cockroach allergen, and, unexpectedly, a low correlation with house dust mite allergen. The authors ascribed this to low levels of house dust mite allergen in January and June, when the measurements were taken.

An interesting finding in this study is that asthmatic children in group four had 3.4 times higher odds of being hospitalized than those in the other three groups. This group also missed school more often, needed twice as many unscheduled asthma-related visits to health care providers, and more often had difficulty sleeping at night. The researchers concluded that cockroach allergen is prevalent in inner-city homes and that cockroach allergy is common among children. When both factors combine, children suffer greater morbidity from asthma.

In other case control studies, Call et al. and Gelber et al. cited this sensitivity to cockroach allergen as an important contributing factor to increased frequency of asthma attacks. In agreement with these two studies, van Wijnen et al. found that the percentage of homes with high levels of cockroach allergens was identical for both patients and controls in adults sensitized and those not sensitized to cockroach. It depends on the presence of allergy in the same individual to develop symptoms on exposure to cockroach allergen.

# 7. Physical Characteristics of the House

## 7.1 Safety in the House

The literature addresses the following issues: the incidence of home accidents among children and the elderly, house fire injuries and fatalities, and preventive measures against home accidents and carbon monoxide poisoning. Defining home safety as a public health issue, this literature emphasises preventive measures to reduce accidents and other hazards in the home. This literature does not define home accidents and provides only a limited examination of the incidence of house fires and other risks inside the home. Many of the studies appear to rely on the reports of local fire officials for the incidence of house fires and report primarily the prevalence of such events, injury, and mortality rates among a population in a city or state.

### Home Accidents

The World Health Organization (WHO) reported in 1986 that accident injuries of all kinds rank fifth among the leading causes of death. Home injuries occur as a result of falls, poisonings, and burns, and most of these accidents are considered preventable. Young children and the elderly are particularly vulnerable (Gielen, Wilson, Faden, Wissow, & et al., 1995) Ranson 1990).

The pattern of accidents among children shifts with hazards of the environment and the child's stage of development (Ranson, 1993). Elderly persons over the age of 75 years account for more than half of all home accidents. These accidents are largely as a result of falls, many of which can be fatal (Ranson, 1990). In fact, elderly people are at greater risk of incurring a fatal home accident than any other group. The tendency of the elderly to tire easily, to be forgetful, and to be apprehensive of modern surroundings and equipment heightens environmental hazards (World Health Organization, 1986, cited in Ranson, 1993). The risk of accidents is further increased by the side-effects of medication for geriatric illnesses or mental illnesses, which may affect normal reasoning capacities (Ranson, 1993).

Studies have demonstrated a close correlation between the number of home accidents and socio-economic characteristics such as income and class (Constantinides & et al., 1986). In poor or substandard housing, there may be an association between accidents and the greater number of hazards present. There may also be an association between accidents and a reduced understanding of hazard risks (Ranson, 1993).

Because home safety crosses too many boundaries and disciplines, no one authority, agency, or profession administers home safety initiatives (Ranson, 1993). Ranson (1993) recommends more efficient systems of recording, monitoring, and investigating accidents in conjunction with enforcement, collaboration, and education to remedy the present epidemic. Professional training for architects and designers should include preventive safety design and home safety design standards and legislation should be adopted. Ranson (1993 :248-255) provides a comprehensive design checklist that could be used by architects and designers. Mood (1993:314-23) provides numerous recommendations focusing on reduction of accidents through housing design.

## House Fires, Burn Injuries, and Mortality

The literature identifies house fires as the primary cause of fire-related mortality in the United States. The primary causes of house fires and child burn injuries are wood-burning stoves, kerosene heaters, and floor furnaces (Quinlan, 1996) and smoking materials (Patetta & Cole, 1990). Unprotected radiators and their pipes were also associated with injuries among inner-city children. Building codes in some cities require that radiators be covered in public places, such as churches, daycares, and schools, but not in private or public housing.

Two studies identified probable causes of house fires. A population-based descriptive study of house fire deaths in North Carolina identified heating units or cigarettes as the causes of most fatal fires (Patetta & Cole, 1990). Of 109 deaths in house fires, 94 per cent occurred in dwellings without smoke detectors. In a later study, Runyan et al. (1992) examined 151 fatal and nonfatal residential fires in primarily rural areas in North Carolina using a case-control design. Fatal fires were most likely to have been caused by heating equipment and smoking materials. The greatest risk of death in a house fire occurred in fires involving mobile homes, fires involving alcohol-impairment, and fires in homes without smoke detectors.

Two studies found associations between socioeconomic conditions and incidence of house fires and the use of home prevention strategies. In an ecologic design with regression analysis, Locke et al. (1986) found that as the percentage of families below the poverty level increases the incidence of burns also increases (r-square =0.98). They also detected a correlation between percentage of people renting accommodation in a region and economic well-being (r-square=0.94). In a cross-sectional survey of parental attitudes towards home fire prevention (n=150), Gielen et al. (1995) found significant associations between family income, housing quality and environmental factors, and the number of injury prevention practices used in the home. However, housing quality may be confounded with family income.

## House Fire Prevention

Three studies evaluated the effectiveness of population-based preventive measures, such as the installation of smoke detectors, in reducing house fires. In a cross-sectional survey of black residents living in public housing in inner-city Memphis, Sharp et al. (1992) found that those who chose to participate in Medicaid Plus were more likely to have smoke detectors and to avoid burns from home tap water than residents who did not participate in the program. Medicaid Plus emphasizes health promotion and disease prevention. Sharp et al. identified a possible selection bias in connection with this program. More than half the residents surveyed did not have a smoke detector, or had one that did not work. They recommended enhancing efforts to increase the use of smoke detectors and decrease excessively hot tap water.

In a case-control study, Mallonee et al. (1996) examined the effectiveness of the Safe Block Project, a comprehensive injury prevention trial, in conveying home hazards and injury prevention knowledge to a poor urban African-American community. They found that Safe Block participants were significantly more likely than non-participants to havefunctioning smoke detectors, syrup of ipecac, safely stored medications, and reduced electrical and tripping hazards.

Using an ecologic design (n=9291), Norman and Streiner (1986) reported that annualized fire-injury rates declined by 80 per cent four years after the implementation of a community-based intervention of surveillance or smoke-alarm giveaway program. Like Sharpe et al. (1992) and Mallonee et al. (1996), they recommend targeted intervention with a smoke-alarm-giveaway program as a way to reduce the incidence of residential fire injuries.

### Carbon Monoxide Poisoning

Carbon monoxide (CO) is an odourless, colourless, tasteless, highly toxic poison that occurs naturally as the by-product of the incomplete combustion of fuels. Early symptoms of CO poisoning are difficult to detect because they may be mistaken for the symptoms of food poisoning or influenza. *The Morbidity and Mortality Weekly Report* (1994) notes that in the United States, there are an estimated 590 deaths annually from unintentional CO poisoning. Caplan et al. (1986) and Rudge (1993) identified faulty heating systems and confined spaces as primary sources or means of distributing CO poisoning.

In summary, the research related to home safety tends to report frequencies. These studies lack more sophisticated analyses and a more thorough investigation of causes to support the claims that are made. A recurring finding in this literature is the value of community- or population-based safety programs to reduce home injuries, house fires, and CO poisoning.

### Design Characteristics of the House

The housing environment can positively or negatively influence people's ability to satisfy their needs in terms of contact with others, privacy, experiences, play and development, structure, identification, and aesthetics (Ekblad & Werne, 1990). However, housing is often designed without reference to specific families or kinds of families (McCray & Day, 1977). The findings of past research suggest that successful adjustment to highrise living is affected by such factors as the nature of the physical structure, social networks, and the adaptability of children (Williamson, 1981). The possibility that housing design may affect health has received limited attention in the literature. The issues with which this literature has been concerned include the floor level and the type of building (for example, detached house, low-rise apartment, highrise apartment).

### Floor Level

Floor level is a research area that has not received a great deal of attention. A review of the literature on mental health and highrise housing by Freeman (1993) concludes that evidence of a positive correlation between mental health and floor level is modest. Mitchell (1971) found a positive relationship between floor level and psychological strain among Hong Kong respondents whose households contained more than one family. In a sample of the wives and children of servicemen in the British army, Fanning (1967, cited in Gillis, 1977) found a direct relationship between the floor level of the apartment and psychological strain. The possibility of a selection factor was ruled out as the study's subjects had no choice in the selection of their dwelling unit.

The findings of a community health survey in Glasgow revealed that living in the upper floors of highrise flats was significantly correlated with the prevalence of mental health symptoms, independent of age and sex. Twice the prevalence of symptoms were found among individuals living on the fifth floor or above in highrise flats, compared to those living in houses or on the lower four floors of highrises (Hannay, 1981).

Using data from a sample of public housing residents in Edmonton and Calgary, Gillis (1977) tested the possibility that women may be more affected by building density and height than men. He investigated whether there was a correlation between gender, floor level, and psychological strain. The results support his hypothesis. A positive relationship between floor level and psychological strain was found for women, whereas a negative relationship between these variables was found for men. Furthermore, an interaction between gender, shared floors, and psychological strain emerged. The findings indicate a lower level of psychological strain among women living in dwelling units containing a shared floor in comparison to women whose floor is not shared. No significant correlation between shared floor and strain was found for men. A study of women living in aggregated dwelling units in Japan found that floor level did not have a significant effect on psychological health status, when the type of dwelling was taken into account (Saito, Iwata, Hosokawa, & Ohi, 1993).

One study investigated floor level and suicidal behaviour. Chiu (1988) found in a Hong Kong study that residents on higher floor levels were no more likely than the general population to attempt suicide.

To determine the independent effect of the height of a dwelling from the ground on mental health requires controlling for social class, size, and quality of the dwelling, stage in the life-cycle, structural features of the block, and the immediate surroundings of the block (Freeman, 1993). However, it is hard to separate these factors since they tend to cluster.

## Building Type

There has been some suggestion that there is a relationship between housing type and psychological health, whereby persons living in highrises or multiple dwelling units are more unhappy about their housing circumstances than those who live in houses (McCarthy, Byrne, Harrison, & Keithley, 1985). This unhappiness may result in the development of psychological distress, and eventually, some form of mental illness. A review of the literature on highrise housing and mental health by Ineichen (1986, cited in Blackman, Evason, & Melaugh, 1989) draws the conclusion that the overall evidence suggests that the mental health of occupants of highrise flats is poorer than that of equivalent households living in different situations. This finding is particularly relevant for families with young children. Edwards et al. (1982) in a study of housing type and stress in Toronto, found that apartment dwellers having a greater likelihood of reporting symptoms of stress.

A survey of occupants of a local authority housing in the northeast of England found that while the highest levels of psychological distress occurred among residents of highrise flats and the lowest among those living in houses, the differences were not significant (McCarthy et al., 1985).

However, the study did find a significant interaction between housing type and housing location. Specifically, the subgroup with the highest levels of psychological distress were individuals living in highrise dwellings in "bad" (hard-to-rent) areas while the least distressed individuals were those living in highrise dwellings in "good" areas. Residents of houses in bad areas had the second highest levels of psychological distress. These results were independent of age, sex, and household class.

A study by Duffy and Wilson (1984) involving elderly residents of congregate public housing and private housing found significantly higher morale among individuals living in congregate housing, highrise buildings, and persons living at the end sections of corridors. However, neither their physical nor mental health was superior. Their hypothesis that social interaction mediated the relationship between building design and morale was not supported.

That the effects of housing type may differ by gender is supported by several studies (Edwards et al., 1982). One study showed an association between psychiatric impairment and multiple dwellings and apartments among males, whereas these types of housing were associated with loss of privacy among females. Women living in highrise flats may also indirectly experience adverse effects to the extent that behaviour problems among children have been found to be more common in these types of buildings (Ineichen & Hooper, 1974).

Security is a major issue in highrise buildings. Threats to security can realistically be considered a health risk and can also result in psychological distress. While installations and improvements to technology are common approaches taken to make residences more desirable, there are a number of convincing arguments to suggest that real security is a process which often comes down to people, since people defend only what they feel involves them (Sutherland, 1986). Van Vliet (1983) also emphasizes the need for planning to include contextual considerations, including factors such as building type and residential location.

## Vulnerable Sub-populations

The possibility that apartment living may have negative effects on the development and well-being of children is virtually a universal concern (Van Vliet, 1983). Spatial considerations, for example, may affect children living in flats in two ways (Stewart, 1970 as cited in Ekblad & Werne, 1990). First, it is acknowledged the restrictions of living in a highrise apartment imposed on the environment and experience of children during their early years may reduce their potential for intellectual development. Simultaneously, space restrictions may affect parents in such a way as to influence the relationships they have with their children.

However, in reviewing the literature on children's experiences of living in highrise flats, Ekblad and Werne (1990) note that although researchers generally agree that there are disadvantages to living in highrise apartments, there is less agreement concerning the nature of these disadvantages and their relative importance. This area of research has suffered from several methodological difficulties. For example, in some of the studies on the impact of apartment living on children, the effects of living in apartments and living in crowded conditions are confounded, despite the fact that they may vary independently (Van Vliet, 1983 as cited in Van Vliet, 1985). Studies on the effects of apartment living have also suffered due to the ad hoc selection of other housing types for comparison (Van Vliet, 1983). Research examining how children are affected by apartment living needs to include validating information directly from children and should employ longitudinal designs through which the impacts of sustained exposure can be investigated (Van Vliet, 1983).

The elderly and disabled are also vulnerable to the negative impacts of living in highrise buildings. Elderly and handicapped persons living in highrises may become passive and feel isolated compared to individuals living in housing around a courtyard (Ekblad & Werne, 1990). The resulting isolation and withdrawal may put these groups at risk for depression. Feelings of loneliness among the elderly may be compounded in situations where the elderly can hear noises coming from other apartments but do not see their neighbours (Ekblad & Werne, 1990).

## 7.2 Overcrowding and Density

It is commonly assumed that living in a crowded environment is unhealthy. This has led researchers to hypothesize about a wide range of outcomes that could be influenced by high levels of household crowding, including psychological health, physical health, and specific bacterial diseases such as those caused by Haemophilus influenzae type b. However, researchers who have set out to empirically demonstrate the deleterious effects of crowding have faced difficulties. Although a substantial number of studies have examined the effects of household density on health, there appears to be little agreement on if and how these effects occur.

Before reviewing the current findings, it is important to distinguish between "density" and "crowding," terms that are often used interchangeably. Density refers to a physical condition concerning the amount of space available, whereas crowding is the subjective experience which results from one's perceived exposure to limited space (Stokols, 1972).What this distinction implies is that high density, or a limited amount of space, does not necessarily lead to a perception of crowding. Although density variables have often been given labels such as "crowding index" and "overcrowding," with a few exceptions, the authors of these studies have used measures of density rather than of crowding.

### Psychological Health

A number of studies have examined the effects of household density on mental health outcomes. It has been hypothesized that high density leads to mental "overload," and that an overabundance of inputs can have an adverse effect on the mind. However, the findings from the literature on psychological health are mixed. A group of studies have found household density to be related to mental health. For example, a large cross-sectional study carried out in Chicago revealed a strong relationship between crowding (persons per room) and poor mental health (Gove, Hughes, & Galle, 1979). A study into health differentials in different parts of London showed that overcrowding was correlated with psychiatric disorders, as measured by hospital episode statistics (Landon, 1996). Data collected using a large-scale household survey in two areas of West Belfast revealed an association between overcrowding and psychological distress among children

(Blackman et al., 1989). Based on interview information collected in Hong Kong, Mitchell (1971) found that high household density did not have an effect on psychological symptoms. More superficial measures of strain such as happiness and worry were found to be affected by density among low-income families.

The results of other studies suggest that density may interact with other factors in its effect on psychological health. A study of low-income residents from two New Zealand cities found an association between housing discomfort and psychological distress (Smith, Smith, Kearns, & Abbott, 1993). This study found that among individuals who were exposed to moderate levels of housing stressors (including small amounts of space per person), social support reduced distress, but this relationship did not apply to individuals who were exposed to high levels of housing stressors. Although cross-sectional in nature, which precludes establishing causation, this study is among the higher quality ones, using multivariate techniques to control for most known confounders, and having an adequate sample size that was geographically representative.

One study included two varied samples, one involving male heads of households living in India, and the other involving American college students. Lepore et al. (1991) found that individuals who lived in high-density households experienced psychological distress as a result of domestic problems (family responsibilities, quarrels with other family members). Low-density residents facing similar domestic problems experienced no adverse psychological effects, however. The inclusion of longitudinal data aided in the establishment of causal order. The authors were able to control for prior symptoms. The results gain further support from the fact that the findings were replicated across two samples with large demographic differences. Its weakness lies in the fact that, while the authors controlled for income statistically and gender by having an all-male sample, other important factors known to affect psychological health, such as race, age, marital status, and household composition, were not controlled for and may be confounding.

Other studies have found no relationship between density indicators and alcohol problems (Kearns, Smith, & Abbott, 1991a) or psychological health in general. (Saito et al., 1993). However, these studies had some limitations. The study by Saito et al. (1993) consisted of a sample that was limited to women in multi-unit dwellings. A complete assessment of the potential effects of multi-unit living, however, would require the use of comparable data of those living in detached houses, who could then serve as a control. Furthermore, the cross-sectional nature of the study precludes establishing causal order. The study also suffers from very low response rates (54.3 per cent), which makes any generalization of the results difficult. Although the cross-sectional study by Kearns et al. (1991a) employed multivariate techniques, the sample was not selected randomly, making generalizations difficult.

There is some suggestion in the literature that the relationship between household density and psychological health may be non-linear, with increased psychological symptoms for both low density housing and high density housing (Gabe & Williams, 1987). In this study, however, it is unclear as to whether the sample was selected randomly. Moreover, although the analyses controlled for a number of relevant variables, the study did not control for other important factors that have been shown to have an impact on mental health, such as marital status, race, and age.

The analysis may also have been affected by problems resulting from multicollinearity among some of the independent variables.

The existence of a non-linear relationship finds support in other studies. For example, using data from a stratified probability sample of residents in public housing developments in Calgary and Edmonton, Gillis (1979) found that respondents in households with the lowest levels of density experienced high levels of psychological strain. There was a weak positive relationship between these two variables among residents in higher household density environments. Although income was controlled for in the sampling design of the study, additional factors that have been shown to influence mental health, such as gender and marital status, were not included.

To the extent that living alone can be thought of as the lowest end of the household density continuum, this research is also relevant to the present discussion. Bojrab et al. (1988) studied a group of elderly residents of a public housing apartment building in Indianapolis using depression as an outcome measure. Four variables were found to explain part of the variance between the CES-D scores of the depressed and non-depressed residents, one of which was living alone. However, since the study was cross-sectional, and it was unclear to what extent sociodemographic characteristics considered to be critical to the development of depression had been included as controls in all of the analyses conducted, no direct causal links among the variables can be established.

## Physical Health

Studies examining the influence of household density on physical health have employed both general physical health indicators as well as the prevalence of particular diseases or infections. Those that employ general measures of physical health generally, find a relationship with crowding indicators. For example, using a random sample of applicants to the Housing Corporation of New Zealand, Kearns et al. (1991a) found that self-reported health status was predicted by housing stress (which includes number of rooms per person). Gove et al. (1979) found a strong association between the experience of crowding and poor physical health with respect to the following indicators: generally getting insufficient sleep, catching infectious diseases, and not being cared for by others when one is sick. Controlling for socioeconomic status and other relevant factors, subjective measures of crowding (e.g., lack of privacy, perceived crowding) were found to have an effect on the physical health of men and women in Bangkok (Fuller, Edwards, Sermsri, & Vorakitphokatorn, 1993). A case study of two areas in West Belfast also found an association between overcrowding and an increase in the proportion of adults stating they were currently ill or suffered from a long-standing illness or disability (Blackman et al., 1989).

An aggregate-level analysis of London boroughs revealed strong correlation between mortality and population per hectare and between mortality and persons per room among individuals 55-63 years of age. This study controlled for social class (Kellett, 1993). The researchers also found associations between carcinoma of the bronchus and crowding, carcinoma of the cervix and population density, diabetes and crowding in younger (aged 15-54) and older (aged 55-64) women and younger men. In addition, the study reported a relationship between chronic bronchitis and crowding for older men and younger and older women, and bronchitis, asthma, and emphysema with crowding in the older groups of both sexes.

A prospective study of preterm infants (≤ 32 weeks" gestation) by Emond et al. (1997) involving the selection of cases and controls from the population of Avon (excluding Bath) revealed an association between overcrowding and an increased incidence of both lower respiratory tract infection and diarrhea and vomiting in the preterm. However, crowding was associated with a decreased incidence of lower respiratory tract infection and diarrhea and vomiting in the term controls. These associations held after controlling for confounding social factors.

In contrast, using data from a representative sample of households in Bangkok, Fuller et al. (1993) found little effect on health of housing quality or objective crowding (persons per room). However, these findings may be partially a result of the sample selection of relatively young adults and the rather general health measures employed in the study.

Among the specific diseases that have been used as outcome measures are infections caused by Haemophilus influenzae type b, Helicobacter pylori, hepatitis B, insulin-dependent diabetes mellitus, and Parkinson's disease. Generally, these studies find an association with household density. A case-control study involving children 18-59 months of age for Los Angeles County found that household size of more than six persons was a significant independent risk factor for Haemophilus influenzae type b infections (Vadheimet al., 1992). A study conducted in Singapore found that sharing various personal and household articles such as a toothbrush, handkerchief, razor and comb, were factors associated with the risk of transmitting hepatitis B infection. Factors not associated with increased risk of transmission of infection included sleeping in the same bed (Goh, Ding, Monteiro, & Oon, 1985). Comparing the seroprevalence of anti-HAV antibodies in Spanish children, Morales et al. (1992) found that the higher prevalence rate for gypsy-family unit subjects was influenced by hygienic-sanitary conditions and overcrowding, while only overcrowding seemed to influence the higher prevalence rate in orphanage residents, in comparison to white-family unit children.

Helicobacter pylori infection has also been found to be associated with household overcrowding among a sample of children aged three to fifteen years in Belfast (McCallion et al., 1996). In a large follow-up study of men and women for whom data on childhood housing conditions were obtainable (Fall, Goggin, Hawtin, Fine, & Duggleby, 1997), the relationship between Helicobacter pylori infection and living in a crowded house was independent of social class. In the 1946 cohort of the National Survey of Health and Development, an association was found between an index of overcrowding and bronchitis and pneumonia (Douglas, 1951 as cited in Golding, 1986).

In contrast, among children from Northern Ireland under fifteen, the lowest rates of risk for insulin-dependent diabetes mellitus were found in sectors with greatest population density (number of children aged under fifteen per square km), highest levels of unemployment, household crowding, and high proportions of rented accommodation (Patterson, Carson, & Hadden, 1996). However, this study employed aggregate-level data, and despite the authors' efforts to reduce the potential for ecological bias by performing a more detailed analysis using smaller geographical units (postal code sectors), extrapolating these results to individuals may still be problematic. A case-control study by Martyn et al. (1995) looked at the effect of early life environment on Parkinson's disease. They found no association between any aspect of the childhood domestic environment, including the standard of domestic amenities and the degree of crowding in the home, and an altered risk of Parkinson's disease. These results are coherent with earlier case-controls studies in which no strong environmental risk factors for Parkinson's disease have been identified.

## Mortality

A group of studies have shown associations between household crowding and various measures of mortality. Landon (1996) found that living in overcrowded conditions was among the most significant indicators of increases in ill-health or mortality from heart disease, respiratory disease, asthma, and tuberculosis. Higher mortality rates of children under four years of age have been found in areas of England and Wales with a high ratio of persons per room (Brennan and Lancashire, 1978 as cited in Golding, 1986). An analysis of geographical distributions of mortality in Scottish communities found significant correlations between stillbirths and perinatal mortality and persons per room, while post-neonatal mortalities was significantly correlated with persons per hectare (Williams & Lloyd, 1990). In a subgroup of subjects who were children at the time a housing survey was carried out in Chesterfield, Coggon et al. (1993) found death rates to be high among individuals whose houses were crowded. In contrast, no associations were found between domestic crowding and mortality from stomach cancer or chronic obstructive pulmonary disease. However, some of these analyses were based on very small subgroups.

A causal relationship between density and various health outcomes has still not been established with any certainty by researchers. Most studies on these issues suffer from various methodological difficulties. For example, the bulk of these studies are cross-sectional (Blackman et al., 1989; Gabe & Williams, 1987; Gillis, 1979; Goh et al., 1985; Gove et al., 1979; Kearns et al., 1991a; Lepore et al., 1991; McCallion et al., 1996; Morales et al., 1992; Patterson et al., 1996; Saito et al., 1993; Smith et al., 1993). Many of the studies do not employ multivariate techniques which allow researchers to control for confounding factors (Blackman et al., 1989; Landon, 1996; Morales et al., 1992). Of those studies which do use multivariate analyses, the list of confounders controlled for is often incomplete (Gabe & Williams, 1987; Gillis, 1979; Lepore et al., 1991; Smith et al., 1993; Williams & Lloyd, 1990). Others suffer from the use of very small samples (Fleming, Baum, & Weiss, 1987), small subgroups (Coggon et al., 1993), very low response rates (Smith et al., 1993), large amounts of missing data (Saito et al., 1993), or are aggregate-level analyses (Patterson et al., 1996). Finally, an issue that goes largely unaddressed in all of these studies concerns the mechanisms, or intervening variables, through which these effects occur.

## Vulnerable Subpopulations

The possibility that certain subgroups are more likely to find themselves living in crowded circumstances is supported by the findings of Cooke (1985), who found families with disabled children to be significantly more likely than control families to be living in overcrowded accommodation. A case-control study involving schizophrenic patients in Denmark revealed a greater frequency of first-admittance schizophrenic patients living in crowded dwellings (Sorenson & Mors, 1992). These individuals were also more likely to endure considerable discomfort as a result of air pollution in their housing environment. A study involving cases of shigellosis (an infectious diarrheal disease) in Manitoba found that the incidence of shigellosis and hospitalization rates among Natives were, respectively, 29 and 12 times those of the rest of the population. The researchers also found a significant association between household crowding and the increased incidence of shigellosis on reserves (Rosenberg et al., 1997).

## 7.3 Indoor Air

Indoor air quality has become a growing public concern. The potential function of airborne microorganisms as determinants of respiratory and general health became the focus of attention in North America in response to the implementation of energy saving measures leading to the collection of previously vented pollutants (Tobin et al., 1987 as cited in Flannigan, McCabe, & McGarry, 1991). At least in the United States, lawsuits have been filed on the basis of illnesses claimed to be related to the quality of indoor air, and some cases have reached the United States Supreme Court (Ross & Lockey, 1994). A considerable range of factors that fall under the broad heading of indoor air pollution have been considered to affect health. Among those which have received attention in the literature are exposure to tobacco smoke, volatile organic compounds, nitrogen dioxide, sulphur dioxide, ventilation, and "sick building syndrome."

### Tobacco Smoke Exposure

Exposure to tobacco smoke has received the most research attention of all indoor contaminants (Yocum, 1982 as cited in Esmen, 1985). It is well established that tobacco smoke plays a prominent role in the indoor exposure to total suspended particulates (Spengler et al., 1981 as cited in Angle, 1988). It has also been defined as the most complex indoor contaminant (Angle, 1988). Two sources of environmental tobacco smoke are sidestream smoke, which is emitted from the burning end of a cigarette, and mainstream smoke, which the smoker inhales and then exhales into the room. Mainstream smoke also comes from gases emitted through diffusion of the cigarette paper during smoking. There are 100 times the concentrations in sidestream smoke than in mainstream smoke of such highly toxic compounds as carbon monoxide, acrolein, ammonia, carcinogenic nitrosamines and naphthylamine, cadmium, nickel, and polonium. Sidestream smoke is also more likely to enter the lungs of a passive smoker.

Environmental tobacco smoke exposure can start in utero and extend throughout childhood (Angle, 1988). Research concerned with the potential health effects of exposureto tobacco smoke has focused on general respiratory conditions as well as more specific outcomes such as asthma, pulmonary function, lung cancer, bronchitis, pneumonia, hydroxyproline/creatinine ratios, chronic ear infections, middle ear effusions, and low birth weight among newborns. The subjects in these studies are primarily children.

Although most studies seem to demonstrate associations between exposure to environmental tobacco smoke and various respiratory illnesses, complete consensus on these relationships has not been achieved. Angle (1988) identified at least seven major studies showing a rising prevalence of respiratory conditions among school-aged children as the number of smokers in the household increased. However, a review of the literature on the effects of parental smoking on children by Hood et al. (1992, cited in Austin & Russell, 1997) suggests that no consistent relationship exists between parental smoking and respiratory symptoms among school-aged children. DeAscentis and Graham (1998), by contrast, conclude that the balance of the evidence implies that increased risks of fatal lung cancer among non-smokers can result from inhaling environmental tobacco smoke. They maintain that the lack of conclusive evidence is due to indirect measurement of exposure to environmental tobacco smoke in the critical studies and potential confounding occurring through unmeasured variables.

Although no consistent relationship between respiratory symptoms and indoor environment was found in a cross-sectional survey of children aged twelve to fourteen in the Scottish Highland Region, an association was found between coughing and maternal smoking, controlling for major outdoor pollution (Austin & Russell, 1997). An increased incidence of lower respiratory symptoms was found to be associated with passive exposure to an additional pack of cigarettes smoked daily in the home in a longitudinal study of white children aged seven to eleven years living in six American cities (Neas et al., 1994). An increase of 30 $\mu g/m^3$ in the annual average indoor concentration of respirable particulate matter with an aerodynamic diameter of <2.5 µm ($PM_{2.5}$), which is roughly the effect of one pack per day of smoking, was marginally associated with an increased cumulative incidence of lower respiratory symptoms. A reduction of 2.6 per cent in volume-adjusted expiratory flow rates was found among children whose mothers smoked during pregnancy. Controlling for other risk factors did not alter these associations. Furthermore, the association between environmental tobacco smoke and nitrogen dioxide was minimized by the sampling strategy through ensuring essentially equal proportions of households with nitrogen dioxide sources in the group of children exposed to smoke in their homes and those not exposed.

An excess risk of asthma among children has been associated with environmental tobacco smoke in a study using a case-control design (Lindfors et al., 1995). Furthermore, the results indicate there was no confounding.

Significant associations between several pulmonary function parameters and exposure to tobacco smoke in the home among females were found by Brunekreef et al. (1985); lower peak flow and Maximum Expiratory Flow at 75 percent of FVC were found in exposed women compared to unexposed women. This study included both cross-sectional and longitudinal data, and pulmonary function values were adjusted for age, height, indoor $NO_2$ exposure, and educational status. However, the large majority of results were non-significant and therefore the few which were significant may have been the result of chance.

A longitudinal study carried out in the Netherlands of children aged six to ten years found an association between respiratory symptoms and exposure to tobacco smoke in the home (Dijkstra, Houthuijs, Brunekreef, Akkerman, & Boleij, 1990). The study revealed negative associations between exposure to tobacco smoke and Forced Expiratory Volume in one second ($FEV_1$), peak expiratory flow rate, and maximal mid-expiratory flow (MEF), adjusting for potentially confounding factors. A significant association also emerged between exposure to environmental tobacco smoke in the home and the development of wheezing.

Six major prospective studies demonstrate an increase in bronchitis and pneumonia in the first two years of life among children whose parents smoked (Angle, 1988).

A cross-sectional survey of children six to nine years of age in the Netherlands revealed that urinary hydroxyproline/creatinine ratios tended to increase with the amount of tobacco smoked in the presence of a child (Verplanke et al., 1987). However, there was no significant association between smoking in the house on the day preceding urine sampling (total and in presence of the child) and the hydroxyproline/creatinine ratio.

A study carried out in Japan by Matsuki et al. (1985) revealed a dose-response relationship in children and non-smoking mothers between the hydroxyproline/creatinine ratio and the number of cigarettes smoked by families. There was a larger effect among non-smoking wives than among children of smoking by husbands/fathers, regardless of season. Schoolchildren were more affected by passive smoking when the smoker was their mother rather than their father.

A case-control study in Guangzhou, China, found an increased risk of lung cancer among non-smoking women associated with exposure to tobacco smoke from their husbands. This analysis controlled for education, occupation, and living area (Liu, Sasco, Riboli, & Hu, 1993).

A link exists between household exposure to tobacco smoke and increased rates of chronic ear infections and middle ear effusions in young children (Angle, 1988). A heightened risk for persistent ear infections may occur among children with nasal allergies and recurrent otitis media who are exposed to environmental tobacco smoke (US Environmental Protection Agency, 1987 cited in Angle, 1988).

The evidence is persuasive that non-smoking, pregnant women exposed daily (for several hours) to environmental tobacco smoke have an increased risk for giving birth to babies of low birth weight (Angle, 1988). These findings suggest that strategies dedicated to lessening the burden of cigarette smoke on children's respiratory system must encompass efforts directed toward pregnant women who are smokers and all smokers in the home, including the father (Neas et al., 1994).

Future research into the decreased growth and development of children of smokers needs to further differentiate the effect of exposure in utero from ensuing childhood exposure and also the involvement of toxins like CO, nicotine, and cadmium (US Environmental Protection Agency, 1987 cited in Angle, 1988).

### Volatile Organic Compounds

The presence of volatile organic compounds in dwellings is primarily the result of building and furnishing materials (Harving, Dahl, & Molhave, 1991). Virtually all materials and products employed in construction, furnishings, consumer products, and pesticides emit organic compounds. Combustion fuels, tap water, and tobacco smoke as well as human metabolism, also generate a substantial variety (Angle, 1988). Examples of organic compounds include propane, butane, limonene, methylene chloride, tetrachloroethylene, benzene, ethanol, methanol, and acetone. The literature to date generally supports the association between volatile organic compounds and various respiratory outcomes.

A study by Norbäck et al. (1995) found a significant relationship between nocturnal breathlessness and volatile organic compounds using a sample of individuals aged 20 to 45 years in Sweden. The authors adjusted for potential confounders such as age, sex, and current smoking habits. Their selection of a region from which to draw their sample where no gas cooking or gas heating was used meant they could examine the effects of volatile compounds on respiratory symptoms where the emission of both volatile compounds and $NO_2$ from gas combustion would not be confounding. However, the cross-sectional nature of the study did not allow the authors to differentiate between exacerbation of symptoms in persons with asthma and induction of new asthma.

An experimental study in which a group of eleven volunteers selected on the basis of substantial bronchial hyperreactivity to histamine inhalation were exposed to volatile organic compounds found that, in comparison to the baseline value, a decline in lung function was induced by exposure to a mixture of volatile organic compounds at a concentration of 25 $mg/m^3$ (Harving et al., 1991). Exposure to 25 $mg/m^3$, a level not unusual in the work environment, produced a decline in $FEV_1$ which was most pronounced in persons with high bronchial sensitivity.

These findings imply that efforts should be directed towards keeping the emission of volatile organic compounds as low as possible, through, for example, appropriate selections of building materials. Raw and Prior (1993) note that although levels of volatile organic compounds generated in new homes are not considered hazardous, they can be offensive and may result in small-scale irritation reactions among a few sensitive individuals. When they are initially occupied, the levels of volatile organic pollutants in new homes can be decreased by ventilation before occupation, avoiding the use of urea formaldehyde foam insulation, and avoiding coal tar products which can emit naphthalene, or using them only with product quality control accreditation.

### Nitrogen Dioxide

Emissions of complex assortments of organic and inorganic gaseous and particulate pollutants can result from burning fossil fuels and wood and plant materials (Angle, 1988). Three products of incomplete combustion are the major contaminants carbon monoxide (see section on home safety), nitrogen dioxide (NO2) and sulphur dioxide.

Cooking with gas and space heating using butane or paraffin heaters without flues may generate concentrations of $NO_2$ in excess of WHO ambient air quality standards and guidelines (Stevenson, 1985). Indoor $NO_2$ levels are invariably higher than outdoor levelswhen cigarette smoking or gas stoves are present. The findings of eight major epidemiological studies investigating the impact of gas cooking on children's lung function were found by Angle (1988) to be inconclusive: three studies using large samples found statistically significant effects on lung function while another five did not.

The previously mentioned study by Verplanke et al. (1987) did not find exposure to nitrogen dioxide to be a close correlate of increased urinary hydroxyproline/creatinine ratio, adjusting for other related factors. However, the existence of major $NO_2$ sources in the kitchen, such as vented and unvented gas-fired waterheaters, showed a significant association with elevated hydroxyproline/creatinine ratios, as a result of a negative relationship with creatinine concentration.

A longitudinal survey of children six to ten years of age in the Netherlands found no relationship between exposure in the home to nitrogen dioxide and respiratory symptoms (Dijkstra et al., 1990). A weak, negative association emerged between maximal mid-expiratory flow and exposure to nitrogen dioxide. No association has been established between indoor exposure to nitrogen dioxide and the development over time of respiratory symptoms. However, the measurement of exposure used may not be representative of short-term peak concentrations of $NO_2$, which are possibly more deleterious than long-term average concentrations.

School-aged children have been the major subjects in many epidemiological studies examining the impact of gas stoves that give out $NO_2$ and other pollutants. However, peak or average exposures to $NO_2$ have not been ascertained in such studies (Angle, 1988). Data from examinations of exposure to nitrogen dioxide and respiratory illnesses imply that the effect size is likely to be small compared to that of involuntary exposure to tobacco smoke (Samet, Marbury, & Spengler, 1988). However, the high prevalence of both gas cooking stoves and childhood respiratory illnesses imply that a relatively slight effect of $NO_2$ is an important public health concern. Samet et al. (1988) recommend that, to discover associations of the small magnitude expected, future research should directly measure exposure as opposed to using surrogate variables. They also suggest that the most suitable populations for study are infants and other likely susceptible groups. Consequently, future research should be designed to incorporate findings such as that of Matsuki et al. (1985), who conducted a study of $NO_2$ exposure among schoolchildren and their mothers in Japan. They found that exposure levels were two to three times higher during the winter than in the summer. Furthermore, $NO_2$ exposure in winter was significantly higher among individuals with non-vented stoves than among those with vented stoves.

The current consensus is that the maximum $NO_2$ level of a large number of homes can reduce pulmonary function in asthmatics (Angle, 1988). Among the control measures available for dealing with nitrogen dioxide are the removal of gasoline engines from the home, the use of pilotless ignitions for gas stoves, the installation of effective hood vents over gas stoves, and isolation of the garage from the indoor space (Samet et al., 1988).

### Sulphur Dioxide

Substantial variation in sulphur dioxide, both daily and diurnally, occurs in homes. Smoking in the home or burning sulphur kerosene in an unvented device can lead to higher indoor $SO_2$ levels. Most studies appear to find some relation between levels of sulphur dioxide and respiratory symptoms, but in many cases the associations are not strong. Asthmatics appear to be particularly at risk to sulphur dioxide exposure; half of asthmatic volunteers endure at minimum a doubling of airway resistance at concentrations below 0.75 ppm SO2 in exposures as brief as one minute (Angle, 1988).

A study of schoolchildren in Ohio found small (2 to 3 per cent) but statistically significant decreases in Forced Vital Capacity (FVC) following episodes of 24-hour total suspended particulates (TSPs) 220 to 420 µg/cu m and $SO_2$ of 280-460 µg/cu m. However, these children did not experience FVC decline after a "sham" episode with TSP = 160 µg/cu m and $SO_2$ = 190 µg/cu m (Dockery et al., 1982 cited in Angle, 1988). Research on schoolchildren in the Netherlands also found small (3 to 5 per cent) but statistically significant decreases in pulmonary function measures (FVC, $FEV_1$, MEF) during and following pollution episodes of 24-hour TSP and $SO_2$ levels up to 200-250 µg/cu m. When pollutants averaged 100-150 µg/cu m there was no effect (Dassen et al., 1986 cited in Angle, 1988).

Significant associations were found in a six-city longitudinal study between higher rates of coughing, bronchitis and lower respiratory disease (without lung function changes) and annual-average TSP levels of roughly 30-150 µg/cu m (Ware et al., 1986 cited in Angle, 1988). No relations within individual cities to TSP gradients were found. The only association with $SO_2$ was found for coughing. A cross-sectional study of young adults in Utah revealed higher rates of persistent coughing and phlegm with annual-average $SO_2$ of 115 µg/cu m in the Utah community with highest exposure compared to three towns with lower $SO_2$ exposure (11-36 µg/cu m range) (Chapman et al., 1985 cited in Angle, 1988). These effects may potentially be the result of intermittent high $SO_2$ peaks.

A longitudinal study involving children in the Southwestern United States found that children from the areas with the highest pollution had significantly increased prevalence of cough (annual average $SO_2$ = 103 µg/cu m; intermittent 3-hour maximums frequently were above 2,500 µg/cu m or ~1 ppm) compared to towns with lower pollution (annual $SO_2$ = 14 µg/cu m) (Dodge et al., 1985 as cited in Angle, 1988). These effects may also be the result of intermittent high $SO_2$ peaks.

## Ventilation

The concentration of pollutants depends upon rates of production and removal, the source, and their dilution by ventilation (Lowry, 1989). The exchange between indoor and outdoor air profoundly affects contaminant levels in a dwelling (Esmen, 1985). Air exchange in residential buildings is chiefly by infiltration, which is affected by the kind of construction, the age of the house, and the weather protection provided. Air exchange rates vary by season and are affected by weather conditions and lifestyle. Unless air-cleaning devices are present, the sole major mechanism for removal of nonreactive gases is air exchange.

In terms of air quality, ventilation can take on two different meanings: (1) the supply of fresh outdoor air to occupied regions of a building and (2) air circulation within a dwelling, not necessarily including the supplementation of any fresh air (Mood, 1993). Healthy dwellings should have both kinds of ventilation. Adequate ventilation is imperative to discourage humidity from reaching unacceptable levels (Collins, 1993). Low air movement and poor building ventilation are also risk factors for heat illness (Collins, 1993). It is necessary to have a degree of air exchange to control the build-up of moisture and to provide fresh air (Markus, 1993). Risks of condensation, smells, other pollutants, and a lack of fresh air result from too little ventilation, although too much can also increase the risk of condensation. Overall reduction of indoor air pollution may be achieved through increased ventilation throughout the structure or in particular areas (Samet et al., 1988).

A cross-sectional survey involving a comparison of naturally ventilated and air-conditioned homes in Honolulu found no significant differences in microbial air contaminants between outdoor air and the air inside naturally ventilated residences (Kodama & McGee, 1986). Fewer fungi were found in the air inside air-conditioned homes, including a significantly smaller number of *Cladosporium* sp., but a significantly greater number of *Aspergillus* sp. were found when compared to the outdoors. There were significantly larger total numbers of Gram positive cocci bacteria inside air-conditioned residences than outside. A preliminary health status survey found more complaints of eye irritation, sneezing, nasal congestion, and coughing among occupants of centrally air-conditioned homes. However, the authors caution that no causal relationship can be drawn between the type of residential ventilation and the health complaints of the occupants based on the findings of their study. They suggest that the *Aspergillus* fungi, which appear to thrive in air-conditioning systems, are ubiquitous.

A case-control study of risk factors for La Crosse virus illness in West Virginia found no evidence that barriers such as window screens and air conditioners, which may segregate mosquitoes from humans, are significant determinants of risk of the disease (Woodruff, Baron, & Tsai, 1992).

A case-control study in Guangzhou, China, revealed a reduced risk of lung cancer for a group of variables indicating superior ventilation, even when adjusting for potential confounders (Liu et al., 1993). In this study, exposure odds ratios of 2.1 for males and 3.6 for females were associated with living in a house that had poor air circulation, adjusting for education, occupation, and a range of other risk factors.

Numerous standards have been set by several agencies and organizations to replenish oxygen used by dwelling occupants to avert a build-up of carbon dioxide and other common air pollutants and to eliminate odours (Mood, 1993). Controlled ventilation can also produce a better level and consistency of indoor air quality while preserving energy efficiency (Raw & Prior, 1993).

### "Sick Building" Syndrome

The symptoms of "sick building" syndrome include irritation of the eyes, nose, and throat, dry mucous membranes and skin, skin rashes, mental fatigue, dizziness, airway infections, coughing, hoarseness, wheezing, non-specific hypersensitivity reactions, nausea, and diarrhea (Molhave, 1985 cited in Angle, 1988). These symptoms occur with no explanation in clusters associated with a specific building. Often the building is relatively new (Lowry, 1989). No single factor, not even psychological distress or hysteria, has successfully explained the numerous physical complaints of occupants of stuffy buildings (Angle, 1988). Most frequently incriminated in sick building syndrome are volatile organic compounds (Angle, 1988).

Several highly important but largely understudied sources of chemical contaminants are house care products, personal care products, and hobbies (Esmen, 1985). Virtually every one of these commodities are marketed under trade names and either by themselves or in combination can produce levels of contaminants instantly dangerous to health (Young et al., 1978 as cited in Esmen, 1985).

## 7.4 Cold, Heat, and Housing

Housing must provide protection from extremes of temperature well as other environmental hazards (Collins, 1993). A restricted range of temperature variation has been established as the source of both thermal comfort and satisfaction. Furthermore, comfort and satisfaction have been found to depend on the capacity to control temperatures and adjust to changes (Nicol, 1993).

The thermal equilibrium of the body is affected by four environmental elements in the indoor climate: ambient air temperature, radiant temperature, air humidity, and air movement. The interaction of these factors generates thermal stress and can cause undue heating or cooling of the body (Collins, 1993). The occurrence of noticeable shifts in indoor conditions are a health threat, particularly for vulnerable groups like the elderly, infants, the sick and the disabled and those who spend most of their time indoors. For example, temperature stress resulting from both daily and seasonal temperature changes has been shown to be related to coronary episodes in Australia (Enquselassie, Dobson, Alexander, & Steele, 1993). Consequently, researchers there advise that improvements in residential temperature control would avert temperature extremes that produce this kind of stress.

There is an apparent association between high levels of mortality in winter and low temperatures (Rudge, 1996). Respiratory and circulatory diseases are the kinds most often associated with wintertime deaths. Rates of mortality for these diseases rise as the temperature drops (Mant & Muir Gray, 1986). Some medical research suggests that mortality peaks in winter are not the result of extremely low temperatures, but of a seasonal fall in mean temperature, regardless of the average annual temperature (Douglas et al., 1991 cited in Rudge, 1996). Thus, relative temperature changes as opposed to absolute temperature levels appear to be involved in the health impact.

There are a number of areas of research related to cold and heating that examine the influence of various housing factors. Among the broader topics considered are therelationships between cold, humidity, and respiratory disorders and the effects of responses to cold on the heart and circulation. For example, several studies carried out in humidified and non-humidified buildings support the hypothesis that there are increases in upper respiratory tract infections when the relative humidity indoors is low (Collins, 1993). Cold air is also viewed as a major trigger of asthma, particularly when accompanied by exercise.

Studies have also investigated the relationship between Sudden Infant Death Syndrome and environmental temperature (e.g. Murphy and Campbell, 1987 cited in Collins, 1993), providing another important avenue of research in the area of housing. In addition, there are groups of studies seeking to demonstrate negative correlations between winter mortality and indoor temperatures (e.g. Boardman, 1986 as cited in Collins, 1993), and risk factors for heat illness in urban areas (e.g. Kilbourne et al., 1982 as cited in Collins, 1993).

Other studies focus on the risks of excessive heat and cold in relation to vulnerable subgroups. Some elders experience "voluntary hypothermia" due to "fuel poverty." These elders try to reduce their expenditures on fuel by setting their indoor temperatures to levels too low for comfort (Collins, 1993). This is particularly problematic because it is harder for the elderly to maintain a constant temperature, since they have a tendency to feel cold more than they did at younger ages (Reddick, 1985).

Another area of research examines mental health outcomes in relation to cold and heat. For example, there is evidence of an association between cold and anxiety and depression (Markus, 1993). There is also some suggestion that individuals with poorer mental health may be influenced by unaccustomed heat stress and the indirect effects of high indoor environmental temperature on sleep patterns (Collins, 1993).

Policy-oriented research constitutes the final area of literature presented. These studies examine such issues as the planning of housing construction to satisfy thermal requirements, taking into account the range of outdoor temperatures, and the establishment of optimum house densities for given sizes of households as a means of reducing underheating and condensation (Markus, 1993).

# 8. Social, Economic and Cultural Characteristics of Housing

There are many conceivable relationships between health and the social, economic, and cultural characteristics of housing. However, there is very little literature addressing what may be one of the more important relationships in terms of psychological health and well-being, which in turn, has significant impacts on physical health.

Access to adequate and appropriate housing at an affordable price is one of the essential human needs for even basic survival. There is a great deal of literature on housing affordability but it does not address the health implications (Bramley, 1994; Feins & Lane, 1981; Feins & White, 1977; Hulchanski, 1994; Hulchanski, 1995; Hulchanski & Michalski, 1994; Lane, 1977; Linneman & Megbolugbe, 1992; Whitehead, 1991). This issue is part of the broader issue relating to socioeconomic status and income inequality discussed in Chapter 3. Low-income households pay a high percentage of their income for relatively poor quality housing compared to higher income households. In Ontario, for example, the housing expenditure-to-income ratio by income quintile in 1992 was: 36 per cent for the lowest quintile; 25 per cent for the 2nd quintile; 20 per cent for the middle quintile; 12 per cent for the fourth quintile; and 7 per cent for the highest quintile (Hulchanski, 1995). What matters is how much money a household has left over for other essentials, such as nutritious food, medicine, and other essential goods and services.

There is some literature on housing tenure and health, and housing satisfaction and health.

## 8.1 Housing Tenure (Owning and Renting)

Housing tenure refers to whether occupants own or rent their housing. It is often hypothesized that tenure is associated with health. A recently published paper (Kind et al., 1998) reports on a survey of the population of the United Kingdom, conducted as part of a wider study of practical ways of measuring health-related quality of life. The sample consisted of 3,395 subjects representative of the general population with respect to age, sex, and social class. The authors report that: "When respondents were grouped according to housing tenure, significantly higher rates of problems were recorded on all the dimensions for those living in rented property compared with owner occupiers."

Housing tenure is also often conceptualized as a proxy for socioeconomic status. Studies have examined associations between housing tenure and various types of cancers, sudden infant death syndrome, and chronic illness.

### Housing Tenure and Cancer

Two studies in Italy examined the association between tenure and cancer (Faggiano, Zanetti, & Costa, 1994); Rosso, 1997). Faggiano et al. (1994) investigated cancer risk and social inequalities in Italy. A case-control study nested in a cohort was analyzed. Cases were subjects who had a new diagnosis of cancer in 1985-87 (n=7,666; 4,215 male cases, 3,451 female cases), and controls were a sample of the Turin population. Cases were matched by gender and age group. They calculated odds ratios (OR) for social classeswhich were defined by education, housing tenure, and socioeconomic group using a logistic regression model. Renters had higher odds of lung cancer and cancers of the upper respiratory and digestive tract.

Using education and housing tenure as proxies for social class, Rosso et al. (1997) studied social differences in cancer survival in residents of Turin, Italy. This was an ecologic design which is frequently used in cancer studies (Norman & Streiner, 1986). Cases were drawn from a cancer registry and were linked to municipality files and 1981 census data. Home ownership was significantly associated with a lower risk for cervical cancer, prostate cancer, and bladder cancer, when controlling for education.

### Housing Tenure and Sudden Infant Death Syndrome

Schluter et al. (1997) designed a case-control study to investigate the association between housing tenure and sudden infant death syndrome (SIDS) in New Zealand. The study period was all sudden infant death syndrome diagnoses that had occurred between 1987 and 1990. Parents of 393 (81 per cent) of these deceased children agreed to participate. Controls were recruited by randomly sampling 1,800 infants born in major New Zealand cities. Parents of 1,592 (88 per cent) control infants consented to participate. They measured the impact of housing type, house size, house ownership, house age, house construction, house warmth, house numbers, and house density on the incidence of SIDS controlling for an array of pertinent other variables. The study found that housing did not appear to be a contributing factor to SIDS (Schluter et al., 1997).

### Housing Tenure, Chronic Illness, and Mortality

Yuen et al. (1990) examined a potential association between self-reported chronic and acute illness in men and women (n=30,000) and housing tenure. The sample was drawn from the General Household Survey, which is an annual sample survey of the population living in private households in Great Britain. Housing tenure was tested as a proxy for socioeconomic status. The odds of having a chronic illness were between 20 per cent and 30 per cent higher for council tenants than for homeowners. The authors acknowledge the limitations of self-reported morbidity, but add that it has been demonstrated in other studies that physicians and patient ratings of health are consistent. Further they suggest that housing could have a more direct effect on health status through overcrowding, lack of heating, and lack of facilities and amenities.

The results suggest an association between housing tenure and morbidity for both sexes with council tenure. Although cross-sectional survey is considered a weak design in epidemiology, this study identifies associations for further exploration. Also, their findings seem to support the findings of previous studies on the influence of socioeconomic conditions and health.

In a longitudinal study, Sundquist and Johansson (1997) investigated the relative risk of mortality for people who reported poor health or whose educational level was low in Sweden. Using a random sample (n=39,156), the study was designed as a follow-up to base-line interviews conducted between 1979 and 1986. Housing tenure was a socioeconomic proxy that was divided into those who rent and all other arrangements. Logistic regression analysis showed that type of tenure at baseline was associated withincreased subsequent mortality risk at all ages and for both sexes when controlling for age, marital status, educational status, and health status, but especially for people between 60 and 74 years of age for both sexes.

The sample size was adequate, and the length of time in which the survey was carried out seems to strengthen the possibility of an association between housing tenure and increased risk for mortality. It is impossible to infer causation between housing tenure and mortality in accordance with standards for establishing causal links in epidemiology. At best, given the design and self-reporting strategies, the study can demonstrate association. It is possible that the association is spurious, if both health and tenure are related directly to socioeconomic status.

## 8.2 Housing Satisfaction

Housing satisfaction is an area of research that has received considerable attention. Much of this literature is concerned with examining the types of factors that may have an influence on satisfaction. For example, among the factors found to affect housing satisfaction most strongly is inadequate space (Kinsey & Lane, 1983). Differences in housing satisfaction have been found between urban and rural residents. The former are more satisfied with inside storage and inside appearance, and that latter are more satisfied with the structural quality of their units and where their units are located in relation to church and social activities (McCray & Day, 1977).

An article by Galster (1985) explicitly questions whether residential satisfaction is the optimal social indicator that can be created to guide housing policy. Galster argues instead that the psychological construct of "marginal residential improvement priority," in which various elements of the residential environment are rank-ordered by individuals in terms of preference for improvement, is a better indicator of households' preferences. As a result, he emphasizes the need for housing policy makers to survey populations to obtain their marginal residential improvement priorities, as opposed to their current residential satisfaction. This will allow maximum "payoff" to be obtained from a given expenditure of targeted housing subsidies. He also notes that the weakest rank-order correlation between relative satisfaction and marginal improvement priority occurred in those groups who have been housing policy makers' primary concern: lower income and elderly households.

In the subsection of the housing satisfaction literature concerned with health, satisfaction has been hypothesized both to have an effect on health and to be an outcome of health.

### Housing Satisfaction as a Factor Influencing Health

The limited evidence available on the effect of housing satisfaction on health finds support for an association. In a cross-sectional survey of individuals applying for subsidized rental dwellings, housing dissatisfaction was found to be a significant predictor of psychological distress, controlling for other relevant factors likely to have an effect on health (Kearns et al., 1991a). A large cross-sectional study in Bangkok found that individuals who said they were satisfied with their housing were less likely to report that they curtailed their daily activities because of illness and had better self-reported health status (Fuller et al., 1993). A study examining the effects of various housing factors on the psychological health status of women living in multi-unit dwellings in Japan found poor psychological health among women who were dissatisfied with their housing plan or with the arrangement of rooms (Saito et al., 1993). In contrast, the results from a survey of low-income residents of two New Zealand cities found no association between housing satisfaction and psychological distress (Smith et al., 1993). However, the cross-sectional nature of this study and the failure to control for gender — particularly since prior research has demonstrated the existence of gender-specific mental health outcomes — suggests that this latter finding should be treated with caution.

Health status may predispose individuals to be satisfied with most things, including their housing. Therefore longitudinal studies would be very helpful in exploring the potential role of causation in the relationship.

The findings of a study of three priority housing action areas in Liverpool suggest an association between capitalized housing improvements and higher levels of housing satisfaction (Hunt & McKenna, ). However, the authors caution that, although improving housing conditions may improve physical and mental health, housing improvement policies should be firmly entrenched in social policies that address the interacting elements that exacerbate social inequalities in health.

### Vulnerable Subpopulations

The well-documented fact that the severely mentally ill usually occupy a poorer quality of housing suggests that housing satisfaction may be a particularly pertinent issue for this group of individuals. Since housing satisfaction may have an impact on the functioning of such individuals, further research in this area is warranted.

A study of chronically mentally disabled clients in Hamilton found significant correlation between housing satisfaction and overall coping ability (Elliott, Taylor, & Kearns, 1990). The authors argue that this finding strengthens the argument that a paramount consideration for the well-being of clients is the perceived quality of the living situation. They argue that housing provision issues must extend beyond matters of supply and demand and encompass issues of suitability for the chronic mentally ill individual. The study also found that housing satisfaction varied considerably even among respondents grouped in terms of housing type, location, and living arrangement, implying that particular living situations suit the needs of specific persons but are inappropriate for others. Extending this logic provides a basis for arguing in favour of a range of housing options and a process for placement that corresponds to clients' needs.

# 9. Summary of Findings

## 9.1 The Current Literature on Housing and Health

This comprehensive literature review delineates the current state of research in the field of housing and health. Much of the general literature on the effects of housing on health cites previous studies of the association between various housing factors and health, and then proceeds to advocate housing policies and strategies aimed at improving population health. Most of this literature provides no original data on the connection between health and housing, and little or no data to support the effectiveness of specific housing strategies for improving health.

Studies providing original data on the relationship between housing and health can be divided into two main categories. The first category involves the study of specific physical, chemical, and biological exposures with a known or suspected effect on health, and which occur primarily or frequently in the household setting. Prototypical exposures in this category include lead and radon. Many of these exposures have been examined extensively using methods from the disciplines of environmental and occupational health. This research takes place within an established theoretical framework involving quantitative exposure assessment, measurement of defined physiological parameters and health outcomes, and calculation of the dose-response relationship between exposure and outcome.

The second category of research on the relationship between housing and health has focused on physical, social, economic, and cultural characteristics of housing. Unlike studies in the first category, these studies often examine complex housing factors such as design and overcrowding that do not easily conform to an experimental model based on exposure to a physical substance. In part because of the lack of a clear experimental model, research in this category has not been as extensive or systematic as in the first category.

## 9.2 Study Design

Before proceeding with a summary of the evidence linking specific housing factors to health, we must first examine certain issues of study design. When we examine the literature on the health effect of a particular housing factor, not all studies should be given equal weight. Certain study designs are superior, in that they are generally more likely to give a true result, whereas other study designs are highly susceptible to bias and error. In the area of housing and health, four types of studies should be considered: cross-sectional studies, case-control studies, cohort or longitudinal studies, and randomized controlled trials. The relative merits of these study designs must be taken into account when weighing the evidence for the effect of housing on health.

**Cross-sectional Studies.**

Cross-sectional studies examine both risk factors and outcomes at a single moment in time. Most health surveys are in fact cross-sectional studies. For example, a researcher could inquire about the presence of mould in the home and simultaneously determine the level of respiratory symptoms in household members. Cross-sectional studies are among the weakest for determining causation, most notablybecause the temporal relationship between the putative cause and effect cannot be determined with certainty. In addition, if the study is not conducted in a well-defined population (for example, all residents of a given community), the study may examine a non-representative group of individuals or households (selection bias). Finally, cross-sectional studies are particularly vulnerable to confounding (see discussion in Phase 2, "Socioeconomic Status, Housing, and Health").

### Case-control Studies.

Case-control studies first identify individuals with the health outcome or disease of interest (cases), and then identify a similar group of individuals who do not have the health outcome (controls). Researchers then ascertain which of the cases and controls were previously exposed to the risk factor of interest. Statistical analyses are performed to calculate the likelihood of disease in persons exposed to the risk factor. For example, cases might be all persons in a community who have been diagnosed with asthma, while controls might be an equal number of persons in the community without asthma. The presence of mould in the homes of cases and controls would then be determined.

Case-control studies, while inherently stronger than cross-sectional studies for demonstrating causation, are also vulnerable to error. Valid results are highly dependent on the appropriate choice of a control group. Of particular concern, the assessment of the presence or absence of the risk factor takes place retrospectively after the health outcome has occurred, and is therefore subject to significant bias.

### Cohort or Longitudinal Studies.

Cohort or longitudinal studies are far superior to either cross-sectional or case-control studies in determining causation. In longitudinal studies, a defined population (the cohort) is identified in which the disease has not yet been diagnosed. The presence or absence of a wide variety of risk factors and baseline characteristics are determined, and the cohort is then followed over time. During the follow-up period, which can last months, years, or decades, the study population is monitored for the development of disease. For example, a study could examine the homes in a given community for the presence of mould, and then follow the persons living in those households to determine which of them developed asthma.

### Randomized Controlled Trials.

Randomized controlled trials are considered the best evidence for a cause and effect relationship. In this type of study, subjects are randomly assigned to receive or not receive the treatment of interest, but are handled the same in all other respects. Subjects are followed over time and assessed for health outcomes. This study design presents obvious practical and ethical problems when applied to the area of housing and health. First, a study randomizing subjects to be exposed to a potentially harmful agent or risk factor is ethically untenable. For example, one could hardly justify deliberately creating high levels of mould in a household and then following the residents to determine whether asthma developed. Second, housing is a complex entity, and it is difficult if not impossible to alter a single housing characteristic while holding all other characteristics constant. It would obviously be very difficult to change a household's density without significantly affecting other features of the housing such as location and size. Third, randomized controlled trials are extremely expensive and time-consuming to conduct, especially when the outcome is rare or the latency between exposure to the risk factor and the outcome is long. For all of these reasons, randomized controlled trials are extremely rare in the area of housing and health.

## 9.3 Criteria for the Demonstration of Causation

A housing factor may be associated with a health outcome, but this association does not prove the existence of a causal relationship. We will briefly review generally accepted criteria for the demonstration of causation in the field of health research. These criteria are time sequence, strength of association, dose-response effect, consistency of results, reversibility of effect, and biologic plausibility. The more of these criteria that are met, the more confidently we can state that a specific housing factor causes a specific health outcome.

### Time Sequence.

Causes must obviously precede effects. For a causal relationship to exist, an exposure to a housing factor should take place before the health effect occurs. Cross-sectional studies that simply demonstrate that a housing factor and a health condition are simultaneously present cannot rule out the possibility that the health condition preceded the existence of the housing factor. In contrast, longitudinal studies are better able to assess temporal relationships.

### Strength of Association.

It is intuitively obvious that a factor that appears to greatly increase the risk of a health problem is more likely to be causative than a factor that only slightly increases the risk of the problem. Longitudinal studies and randomized controlled trials often express the association between a factor and an outcome in terms of relative risk. Relative risk is defined as the risk of the outcome in persons exposed to the factor, divided by the risk of the outcome in persons unexposed to the factor. For example, smokers are approximately 10 times more likely to develop lung cancer than non-smokers (a relative risk of 10), but only about 3 times more likely to have a heart attack (a relative risk of 3). These observations would constitute stronger evidence to support a causative link between smoking and lung cancer than between smoking and heart attack. In case-control studies, results are often expressed as odds ratios, which usually provide a reasonable approximation of relative risk. A finding of a high relative risk or high odds ratios strengthens the case for a causal relationship.

**Dose-Response Effect.**

If an exposure causes an adverse health effect, a higher or more intense exposure would be expected to result in a more severe effect. This relationship is easy to demonstrate for certain exposures such as lead; low level of lead poisoning cause subtle behavioral changes in children, whereas high levels of lead poisoning cause frank mental retardation. In a less clear-cut example, if high household density does in fact cause psychological distress, higher household density should be associated with more severe distress (as measured using quantitative psychological assessment tools). It is worthwhile to note that if a housing factor is characterized as either present or absent, it will be impossible to test for a dose-response effect.

**Consistency of Results.**

A causal link between a housing factor and health is more likely to exist if an association is observed under various circumstances and in multiple studies. Causality is particularly plausible if different research groups using several different research designs reach the same conclusions. Ideally, a similar effect should be observed in studies performed in different geographical regions or countries. If evidence from multiple studies are conflicting, however, one well designed study should be given more credence that several poorly designed ones.

**Reversibility of Effect.**

Studies may show that the presence of a putative causative factor is associated with an increased risk of disease. A very strong case can be made for causation if removal of the factor is associated with a decreased risk of disease. In the example of household density cited above, moving a family from high density housing to a residence with lower density (all other factors remaining equal) should result in decreased psychological distress. While such a finding would constitute strong support for a causal relationsnip, this kind of evidence is rarely found in studies of housing and health.

**Biologic Plausibility.**

Biologic plausibility rests on whether a purported cause-and-effect relationship is consistent with the current understanding of mechanisms of disease. For example, the adverse effect of lead on health can be explained by known physiological mechanisms, whereas mechanistic explanations for a link between electromagnetic fields and health effects are much more tenuous. When biologic plausibility is present, the case for causation is easier to make. Sometimes, however, lack of biologic plausibility reflects limitations in our current knowledge of mechanisms rather than absence of a causal relationship. The issue of mechanisms is discussed further in Phase 2 of this project ("How Does Housing Affect Health?").

## 9.4 Overall Strength of Evidence

The findings of our literature review are presented below and are summarized in Table 1. Each housing factor or characteristic is considered individually. Estimates of the size of the Canadian population exposed to each factor are not provided, because in most cases reliable quantitative data are not available.

A qualitative rating is given for the strength of the evidence supporting a causal relationship between the housing exposure or characteristic and the health effect. The criteria for each rating is as follows:

- **Definitive** (numerous well-designed studies showing the effect, most or all causal criteria met, essentially complete agreement among experts that a health effect exists)
- **Strong** (some well-designed studies showing the effect, most causal criteria met, preponderance of opinion among experts that a health effect exists)
- **Possible** (small number of studies showing the effect, some or few causal criteria met, no consensus among experts that a health effect exists)
- **Weak** (conflicting or negative evidence regarding the effect, few or no causal criteria met, consensus among experts that a health effect is not proven or unlikely)

This rating takes into account a number of considerations, including the number, design, and quality of studies in that area, the number of criteria for causation that have been met, and expert opinion. In general, the ratings should be treated as best estimates rather than conclusive findings. Due to the paucity of data on the size of the population exposed to each factor and, in many cases, uncertainty regarding the magnitude of the health effects of each factor, the relative "seriousness" of the various hazards cannot be reliably ranked.

### Specific Physical or Chemical Exposures

***Lead***: Lead is potent toxin that causes anemia and neurological and intellectual deficits, particularly in children. Exposure typically occurs in older or deficient housing where peeling leaded paint is found. Various screening and treatment strategies are effective in reducing morbidity due to lead poisoning.

***Radon***: Radon is a radioactive gas that accumulates in houses, primarily after emerging from the soil. Radon exposure causes lung cancer in uranium miners, but the magnitude of risk associated with the much lower levels of exposure found in residential settings has not been determined with precision. Despite this fact, the evidence for significant health risk in housing with radon levels at the high end of the residential spectrum should be considered very strong. Future studies are likely to make this link definitive.

***Asbestos***: Asbestos is a proven carcinogen associated with malignant mesothelioma and other cancers of the respiratory and gastrointestinal tract. The level of risk associated with the levels of exposure typically found in housing where asbestos is present is probably very low but non-zero.

***Electromagnetic Fields (EMF)***: Exposure to EMF in the household setting usually occurs when homes are located close to high-current electrical power lines. The potential health effects of

EMF have been the subject of extensive debate since the initial report of an association between EMF and childhood cancer mortality in 1979. Results of subsequent research has been conflicting, with some finding an association between EMF and illness and others not. A comprehensive review of the literature by the National Research Council has determined that currently available scientific evidence neither proves nor disproves that EMF has any adverse effect on health.

*Urea Formaldehyde Foam Insulation (UFFI)*: Urea Formaldehyde Foam Insulation is postulated to affect health primarily through the release of formaldehyde into the air during and shortly after installation. Studies of the effect of UFFI on chronic respiratory problems have yielded conflicting results. The evidence for an adverse health effect of UFFI is suggestive, but certainly weaker than in the case of lead, radon, or asbestos.

## Specific Biological Exposures

*Dampness and Mould*: The independent health effects of dampness and mould in housing are somewhat difficult to separate, since the two factors are closely linked and often present simultaneously. A modest number of studies have examined the effect of dampness and mould on the incidence of asthma, respiratory tract infections, respiratory symptoms, rheumatic fever, and psychological distress. While the methodological quality of these studies varies widely, significant associations between dampness and mould and health conditions have been frequently found. This association is not unexpected in view of the plausible causal link between fungal allergens and immunologically mediated respiratory illnesses. Current evidence should be considered suggestive but not conclusive in this regard.

*House Dust Mites*: High levels of house dust mite antigens have been shown to be strongly correlated with asthma symptoms, particularly in allergic individuals. Evidencefor a causal relationship is very strong. High humidity and the presence of carpeting and upholstered furniture are associated with higher levels of dust mite antigens; most abatement strategies are directed at these factors.

*Cockroaches:* A number of studies have provided evidence of a causal relationship between the presence of cockroach antigens in the home and asthma, especially among children living in inner city areas where exposure levels are high. As in the case of house dust mites, an allergic mechanism has been demonstrated and thus the effect is biologically plausible.

## Physical Characteristics of the Home

*Various Characteristics / Home Safety*: A wide range of physical characteristics of the home, including the presence or absence of stairs, safety devices, and physical hazards or obstacles, are associated with the risk of falling at home. The causal relationship between these characteristics and falls is obvious, particularly in the case of stairways. Serious injuries and deaths due to falls in the home are particularly common among the elderly. Efforts to reduce this risk require a cooperative effort between health and housing experts.

*Heating Systems*: Home heating devices such as wood-burning stoves and kerosene heaters can cause house fires that lead to death or injury from burns or smoke inhalation. In addition, direct contact with hot surfaces such as radiators or stoves can cause burn injuries. Residents in poor neighborhoods are at particularly high risk for all of these types of injuries. In addition, defective or malfunctioning heating systems are the leading cause of unintentional carbon monoxide poisoning.

***Smoke Detectors***: Smoke detectors have been shown to reduce the risk of injury and death due to house fires. Research studies have identified intervention strategies that are effective in increasing the use of home smoke detectors.

***Carbon Monoxide Detectors***: Wider use of carbon monoxide detectors has been advocated as a strategy to reduce injuries from carbon monoxide poisoning. No studies have tested the effectiveness of this approach.

***Floor Level***: A small number of studies have found that persons living on higher floor levels of multiple-floor dwellings have higher levels of psychological distress than persons living on lower floor levels of these dwellings. These findings suggest a possible causal relationship.

***Building Type***: A small number of studies have found that living in a high-rise structure (as opposed to living in a low-rise structure) is associated greater psychological distress and poorer physical health. These studies are limited by significant methodological weaknesses, including the role of confounding factors such as income.

***Density and Overcrowding***: Numerous studies have examined the relationship between household density (or overcrowding) and psychological distress, general physical health, mortality, and various diseases. Not surprisingly, high household density and overcrowding have frequently been found to be associated with adverse health outcomes. Many of these studies, however, suffer from significant methodological limitations such as cross-sectional design and a limited ability to rule out confounding factors such as poverty. Thus, the evidence regarding the effects of household density on health can be regarded as plausible and suggestive, but not robust.

***Environmental Tobacco Smoke (ETS)***: Tobacco smoke, which contains a large number of carcinogens, has been proven to cause numerous health problems in smokers. A large number of studies now support a causal link between environmental tobacco smoke and various health problems. Children exposed to tobacco smoke are at increased risk for asthma, bronchitis, pneumonia, and ear infections. In utero exposure to ETS is associated with low birth weight, and adults exposed to ETS are at increased risk of lung cancer. The elimination of ETS from the household setting can be achieved much more effectively by behavioral measures (that is, the avoidance of smoking indoors) than by changes in housing design such as improved ventilation.

***Volatile Organic Compounds***: Volatile Organic Compounds are released into the air by building and furnishing materials, especially in new houses. To date, studies suggest that exposure to these compounds exacerbate respiratory symptoms, particularly in susceptible individuals such as those with asthma. There is currently little evidence for other more serious health effects.

***Nitrogen Dioxide***: Nitrogen dioxide, a product of incomplete combustion, is produced in the residential setting primarily by gas-fueled stoves and space heaters. Studies of the association between cooking with gas stoves and respiratory symptoms have yielded conflicting results, and a causal link has yet to be demonstrated convincingly.

***Sulfur Dioxide***: Sulfur dioxide probably exacerbates respiratory symptoms, particularly in persons with pre-existing lung disease such as asthma or chronic bronchitis. However, exposure to sulfur dioxide is largely determined by atmospheric pollution (from car exhaust and electricity generation plants) rather than by housing factors. The most important source of sulfur dioxide in the home is smoking; measures to reduce environmental tobacco smoke would also reduce household sulfur dioxide exposure.

***Ventilation***: Adequate ventilation can reduce levels of indoor air pollutants and maintain appropriate humidity levels in the home, and would be expected to affect health through these factors. The effect of ventilation per se on health has not been well studied.
***Cold and Heat***: Extremes of cold and heat can obviously cause adverse health outcomes; housing that protects against these extremes is essential to health. Rapid changes in temperature can also be deleterious to health and should be guarded against.

### Social, Economic, and Cultural Characteristics of Housing

***Housing affordability***: Data on the effect of housing affordability on health are inadequate to draw conclusions at this time.
***Housing tenure***: Housing tenure (whether housing is rented or owned) is both a characteristic of housing and a proxy indicator of socioeconomic status. A number of studies have found that home ownership is associated with favorable health effects on cancer incidence and survival, general physical health, and mortality. While these associations are consistent and strong, it is likely that this effect is mediated by socioeconomic status and is not a direct effect of housing tenure.
***Housing satisfaction***: Satisfaction with housing has been found to be correlated with psychological health. Whether satisfaction with housing causes improved psychological health, or vice versa, is unclear.

## 9.5 Limitations of the Literature Review

Certain limitations of this literature review should be noted. As with any literature review, our search strategy may not have identified all relevant articles. While a broader search strategy might have identified some additional articles of interest, it would also have selected a far larger number of extraneous articles and would have greatly lengthened the time required to manually review all of the abstracts. The search strategies used for this literature review were chosen to balance the goals of being both comprehensive and efficient.

Another limitation of this literature review was it included only articles published after 1983. The decision to focus on the recent literature was based on time constraints and on the considered opinion of the principal investigators that the most important and relevant studies in this area have been published in the last 15 years. It should be noted that whenever the retrieved articles referenced studies published prior to 1983 that appeared to be highly relevant, these studies were obtained as well.

Finally, all literature reviews are constrained by the literature as it exists at the time of the review. Unpublished studies are typically not identified; in particular, negative studies (studies that do not find a significant association between a risk factor and a health outcome) are somewhat less likely to be published. In addition, studies not published in indexed academic journals are extremely difficult to identify systematically, and may represent a significant number of studies in the field of housing and health.

It is important to acknowledge that the quantity of literature on a given housing factor does not necessarily reflect the relative importance or prevalence of that factor or the size of its impact on population health. In particular, new and actively developing areas of research may not have accrued a body of literature as large as older, more mature areas of research. The quantity of literature on a given housing factor may also reflect the willingness of government agencies and industry to sponsor such research, and/or the desire of researchers to focus on that area of inquiry. These factors may not reflect the true importance of an area of research in terms of its population health effect.

TABLE 1

## Housing and Population Health: Summary of Findings from a Comprehensive Literature Review

| Type of exposure | | Health Effect(s) | Strength of Evidence* |
|---|---|---|---|
| Specific Physical or Chemical Exposures | Lead | Neurological and intellectual deficits, Anemia | Definitive |
| | Asbestos | Lung cancer, Mesothelioma, Gastrointestinal cancers | Definitive |
| | Radon | Lung cancer | Strong/Definitive |
| | Urea Formaldehyde (UFFI) | Asthma/chronic respiratory conditions<br>Respiratory tract cancer | Possible |
| | Electromagnetic Fields | Cancer incidence, Pregnancy outcomes, Psychological distress | Weak |
| Specific Biological Exposures | Dampness / Mould | Asthma | Possible |
| | | Respiratory symptoms | Possible |
| | | Respiratory tract infections | Possible |
| | | Psychological distress | Possible |
| | | Rheumatic fever | Possible |
| | House Dust Mites | Asthma | Strong/Definitive |
| | Cockroaches | Asthma | Strong/Definitive |

| | | | |
|---|---|---|---|
| *Physical Characteristics* | Various characteristics, Home Safety, Stairways | Falls | Definitive |
| | Heating System | Burns, Smoke Inhalation | Definitive |
| | | Carbon monoxide poisoning | Definitive |
| | Smoke Detectors | Burns, Smoke Inhalation | Definitive |
| | Carbon Monoxide Detectors | Carbon monoxide poisoning | Possible |
| | Building Type | Psychological distress | Possible |
| | Floor Level | Psychological distress | Possible |
| | High-rise Structure | Psychological distress | Possible |
| | | General physical health | Possible |
| | Overcrowding and Density | Psychological distress | Possible |
| | | General physical health | Possible |
| | | Mortality | Possible |
| | | Haemophilus influenzae type B infection | Possible |
| | | Helicobacter pylori infection | Possible |
| | | Hepatitis B infection | Possible |
| | | Type I Diabetes mellitus | Possible |
| | Environmental Tobacco Smoke (ETS) | Asthma, Bronchitis, Pneumonia, and Ear Infections in Children,<br>Low Birth Weight,<br>Lung Cancer | Strong |
| | Volatile Organic Compounds | Respiratory Symptoms | Possible/Strong |
| | Nitrogen Dioxide (Gas Stoves) | Respiratory Symptoms | Possible |
| | Sulfur Dioxide | Respiratory Symptoms | Possible |
| | Ventilation | Respiratory Symptoms<br>Various Infectious Agents | Possible |
| | Cold and Heat | Heat Stroke, Mortality,<br>Respiratory Tract Infections<br>Cardiac Events | Strong/Definitive |
| *Socioeconomic Characteristics* | Housing Tenure | Cancer Incidence | Possible |
| | | Cancer Survival | Possible |
| | | Sudden Infant Death Syndrome | Weak |
| | | General Physical Health | Possible |
| | | Mortality | Possible |
| | Housing Satisfaction | Psychological Distress | Possible |

* "Strength of Evidence" is a qualitative rating of the strength of the evidence supporting a causal relationship between the housing exposure or characteristic and the health effect.
The rating scale is based on the following guidelines. See text for discussion of study designs and criteria for causation.

(1) Definitive (numerous well-designed studies showing the effect, most or all causal criteria met, essentially complete agreement among experts that a health effect exists)

(2) Strong (some well-designed studies showing the effect, most causal criteria met, preponderance of opinion among experts that a health effect exists)

(3) Possible (small number of studies showing the effect, some or few causal criteria met, no consensus among experts that a health effect exists)

(4) Weak (conflicting or negative evidence regarding the effect, few or no causal criteria met, consensus among experts that health effect is not proven or unlikely)

# 10. Implications for Further Research

This chapter draws upon the body of housing/health literature with a focus on outlining findings and analysis relating to two practical issues:

1. the implications for improved methodology for carrying out further research on the housing/health relationship; and
2. the implications for policy making and program design in the area of housing and health.

## 10.1 Does Housing Affect Health?

Given that housing is a necessity of life and a dominant part of our daily environment, it seems logical to conclude that housing affects the health of individuals and populations. Our review of the literature, however, shows that the question "Does housing affect health?" cannot be answered through scientific study. Research can answer only specific questions such as "Does damp housing, as measured objectively by humidity levels, cause an increase in the prevalence of respiratory symptoms?" Using these kinds of questions, researchers can shed light on the relationship between housing and health.

Finding an association between a housing factor and a health condition does not, however, mean that a cause-and-effect relationship exists between the two. An association between a housing factor and a health effect can be explained in at least five possible ways:

1. The housing factor causes the health effect.
2. The housing factor contributes to the health effect, but is not sufficient in and of itself to cause the health effect.
3. A confounding factor, such as socioeconomic status, causes both the housing factor and the health effect; but the housing factor on its own does not cause the health effect.
4. The health condition caused the housing factor to be present, typically through the health condition's adverse affect on socioeconomic status (reverse causation).
5. The association is not a true association, but due to bias or chance (type I error).

Nevertheless, the body of literature summarized in the literature review provides clear evidence that certain aspects of housing have significant health effects.

### How Does Housing Affect Health?

Although the mechanisms through which specific aspects of housing affect health are extremely complicated (see Figure 1 "Conceptual Model of the Housing/Health Relationship" and the discussion in Chapter 3 of the literature review), clarifying these mechanisms is essential.

First, one of the scientific criteria for determining causation is a plausible mechanistic explanation linking the putative causative factor and its effect (biologic plausibility). Merely observing associations between housing factors and population health does not provide convincing evidence of causation if there is no clear mechanistic explanation.

Second, as long as mechanisms remain uncertain, it is entirely possible that many of the correlations between housing and population health are due to confounding by otherfactors, such as socioeconomic status.

Third, knowledge about mechanisms greatly enhances the ability of researchers to focus on and measure relevant exposures and outcomes.

Fourth, identifying specific mechanisms that link housing to health facilitates the development of effective housing interventions to improve health. These issues are best illustrated by two housing factors discussed in the literature review: radon and housing tenure.

*Radon.* The link between low-level residential exposure to radon and lung cancer has been extensively studied but remains controversial. However, research in this area has benefited from the existence of a clear mechanism linking *high* levels of inhaled radon gas to lung cancer (i.e., the mutagenic effect of ionizing radiation). Thus, the finding of a correlation between *low-level* exposure to radon and adverse health outcomes would be considered plausible evidence of a causative relationship, rather than an interesting but unexplained association.

Although there is always a possibility that confounding factors or chance error are involved, the possibility is less likely than in cases in which there is no clear mechanistic explanation for an observed association. In addition, mechanistic explanations allow researchers to focus on relevant health outcomes (in the case of radon, lung cancer) rather than those that are mechanistically less plausible (for example, depression). Finally, knowledge of the mechanism leads directly to potential housing interventions to protect health, such as the installation of special home ventilation systems.

*Housing Tenure.* The association between housing tenure and health indicators lacks any clear or generally accepted mechanistic explanation, therefore a well-designed study that convincingly demonstrated an association between housing tenure and health would not be considered sufficient evidence for a causative relationship. Housing tenure is correlated with potential confounding factors such as income, education, and the social environment. Thus, even if people who rented their housing were consistently found to be less healthy than people who owned their housing, one might reasonably conclude that this was because the renters were poorer, not because they were renters *per se*.

In the absence of a clearly defined mechanistic link between housing tenure and health, researchers have examined health outcomes as disparate as cancer, Sudden Infant Death Syndrome, and general physical health. This lack of focus reduces the effectiveness of the entire research endeavour in this area. Furthermore, the lack of a mechanistic explanation makes any effort to use housing tenure as a health intervention questionable. Although many experts advocate programs to reduce residential exposure to radon to prevent lung cancer, few if any would advocate a program to encourage home ownership as a cancer prevention measure.

These examples show the importance of determining not only *whether* housing affects health but also *how* housing affects health. In general, efforts to define these mechanisms are more advanced in relation to physical, chemical, and biological exposures and physical characteristics of housing than in relation to social, economic, and cultural characteristics of housing. This pattern can be explained by a number of factors.

- First, certain housing factors are more easily defined and quantified (for example, lead concentrations measured in parts per million, or the presence or absence of a smoke detector) than others (for example, housing density or housing affordability).
- Second, health research lends itself more readily to analyses of the effect of physical-chemical factors on biological systems.
- Third, by their very nature, social, economic, and cultural housing factors are complex, multidimensional, and interrelated. Any effort to isolate a single mechanism by which any of these factors exerts an influence on a specific health outcome is extremely difficult if not impossible. This problem is inherent in the study of the socioeconomic determinants of health and is not limited to the area of housing and health.

Although the complexity of the interaction between socioeconomic housing factors and health is daunting, however, this should not discourage further research in this important field.

## Socioeconomic Status, Housing, and Health

The role of socioeconomic status plays a central role in our efforts to understand the connection between housing and health. Abundant evidence from recent research demonstrates that low socioeconomic status at both the individual and population levels is strongly associated with various adverse health effects. At the same time, lower socioeconomic status causes individuals and populations to live in lower quality housing (however defined). As a result, populations living in lower quality housing have poorer health. However, this association cannot be assumed to constitute evidence that the lower quality housing *caused* the health problems. One would be equally justified in concluding that poverty caused both poor health and poor housing. This relationship is known as confounding, and socioeconomic status is referred to as a confounding factor in the effort to analyze the association between health and housing.

The analysis of this problem is complicated by the fact that the association between socioeconomic status and health is not completely understood. To some extent, low socioeconomic status *per se* has an adverse impact on health, presumably because low status within a social group results in higher stress levels, mental and emotional distress, and impaired physical health, possibly through psychologically mediated effects on the immune system. Another possible explanation for the link between socioeconomic status and health is that persons with low socioeconomic status are more likely to have personal habits that adversely affect health, such as smoking, excessive alcohol consumption, substance abuse, and a sedentary lifestyle. Yet another explanation is that persons with low socioeconomic status cannot afford amenities that directly affect health. These amenities include, among other things, housing. Thus, to an extent that is currently undetermined, the undisputed effect of socioeconomic status on health may be mediated in part through housing itself. If this is the case, socioeconomic status is not a confounding factor but a mechanism through which socioeconomic status affects health.

Finally, health status may have a direct impact on housing. When poor health affects an individual's employment status and income, that individual may be forced to move into less expensive housing. Assuming that less expensive housing is more likely to have specific health-related characteristics, this effect could explain an association between these characteristics and poor health. This association between housing and health does not occur because the housing characteristic caused poor health, but because poor health resulted in a shift to a certain kind of housing. This phenomenon is known as "reverse causation." This effect would be expected to be less pronounced among individuals withsubstantial financial resources, who typically do not suffer a decline in housing status when their health deteriorates. Because of the possibility of reverse causation, studies of the effect of housing on health must determine whether the onset of health problems preceded or followed the occupation of the housing.

The intertwined relationships of socioeconomic status, health, and housing makes it imperative to clarify the mechanisms linking housing to health outcomes. For example, poor children are more likely to suffer from health problems such as developmental delay, as well as having lower IQ scores. In certain urban areas, these problems may be linked to lead toxicity. Without understanding the mechanisms of lead poisoning and lead toxicity, one might simply conclude that poverty *per se* leads to developmental delay and lower IQ levels. In light of current knowledge, however, this association is correctly understood to reflect the fact that poor people usually live in substandard housing in which lead levels are high, leading to lead poisoning, which causes developmental delay and leads to lower IQ levels. In this example, the housing factor (lead) directly causes a health effect independent of poverty, and interventions targeted at housing itself would be expected to reduce the health problem.

Socioeconomic status also affects health in indirect ways. These indirect effects occur because socioeconomic status is related to an individual's awareness of housing factors that affect health and his or her ability to act on such knowledge. For example, persons with higher socioeconomic status are more likely to assess their housing for the presence of lead paint, and if lead paint is present, they are better able to deal with the problem. To give another example, persons with higher socioeconomic status are more likely to recognize the benefits of smoke detectors and better able to afford them.

This analysis suggests that whenever researchers try to demonstrate a relationship between housing and health, they must also consider whether a mechanism linking the housing factor to the health outcome has been clearly established. If not, the burden falls on the researcher to find a mechanistic explanation for the observed association. For example, no generally recognized mechanism explains why persons living on the upper floors of high-rise apartment buildings should have higher levels of emotional distress. If such an association is observed, the researcher must determine if the effect can be explained through mediators such as social isolation, physical stimuli, or other means.

### Vulnerable Populations

Particular populations such as seniors, Aboriginals, persons with disabilities, children, and women are more likely to have lower socioeconomic status or to live in poverty than other populations. They are thus more likely to live in lower quality housing and to have poorer health. They may also have specific housing needs, the absence of which can lead to poorer health. Numerous studies have examined the health status of these vulnerable populations; other studies have focused on housing conditions in these groups. However, very little research has examined the effect of housing on health in specific vulnerable populations. Further research in this area is needed. The perspectives of members of these populations should be taken into consideration in designing such research.

## 10.2 How Can We Better Measure the Effect of Housing on Health?

Efforts to improve the measurement of the effect of housing on health can be categorized as either general or factor-specific. General approaches are those that are broadly applicable across various housing factors and often have sweeping implications for research design in the area of housing and health. Factor-specific approaches are usually relevant only to a specific housing factor (for example, dampness and mould) and often focus on narrow methodological issues. The latter are important to investigators addressing specific research questions, but are less useful for understanding the broader implications of the effect of housing on health.

As part of the comprehensive literature review, we identified numerous factor-specific approaches to improving the measurement of the effect of a given housing factor on health. These approaches are summarized elsewhere in this paper. Important general approaches towards improving the measurement of the effect of housing on health are outlined below.

### Study Design

A single, large, well-designed study carries more scientific weight than many smaller, lower-quality studies. Many studies on the effect of physical, chemical, and biological exposures fall into the former category whereas much of the research into the health effects of the social, economic, and cultural characteristics of housing fall into the latter category. A better understanding of these latter issues is more likely to result from more ambitious research designs than from simply increasing the number of studies performed.

Many of the studies in the literature we reviewed were cross-sectional. This type of study is the least effective for determining causation, because the temporal relationship between the putative cause and effect cannot be specified with certainty, and the ability to control for confounding factors is limited. Case-control studies, in which individuals with and without the health outcome of interest are examined for their exposure to the risk factor of interest, are a better way to assess causation. However, this type of study usually relies on the retrospective determination of previous exposures (for example, asking the parents of children with leukemia whether they ever lived near high-tension electrical transmission wires). Even better for assessing causation are longitudinal studies, in which individuals are assessed for risk factors and then followed over time to determine which persons develop the health outcomes of interest. Examples of this type of study include the Framingham Heart Study and the longitudinal component of the National Population Health Survey.

The best study design for assessing causation is the randomized controlled trial, in which individuals are randomly assigned to either the treatment of interest or to a comparison or control group that does not receive the treatment. Participants are then followed over time to determine health outcomes. However, although this type of study is well suited to drug trials, it poses obvious practical and ethical difficulties when applied to housing.

First, random assignment is a questionable practice in the area of housing. Forexample, one cannot justify randomly assigning persons to public housing that was overcrowded in order to observe the effects of overcrowding. However, if people already live in overcrowded housing and a limited number of less crowded housing units are available, one could justify selecting households to move into the less crowded units and observing the effects on their health. Second, and perhaps more importantly, the randomized controlled trial is based on the assumption that the treatment and control groups are identical except for the treatment being tested. Such a condition is rarely achievable in the realm of housing, since housing conditions are typically linked to many other factors that affect health. For example, densely populated public housing usually differs from low-density public housing in a number of ways, including demographic composition, neighbourhood, and community resources.

Researchers in the area of health and housing should consider the following strategies to improve research design.

First, researchers should make a long-term commitment to creating a longitudinal database of housing factors and health outcomes. Such a project would provide a unique opportunity to assess housing factors and observe their effect on health over time. The Framingham Heart Study, a massive undertaking that followed thousands of individuals over decades, resulted in landmark discoveries such as the role of high blood pressure as a risk factor for the development of heart disease.

A longitudinal study of housing factors on health could be carried out at relatively modest cost by participating in the National Population Health Survey, an ongoing longitudinal survey of the health of a cohort of Canadians. Including questions in the survey that specifically assess housing factors, and correlating the results to the development of health outcomes over time, would provide unprecedented, representative, longitudinal Canadian data. Because many different health, psychosocial, and demographic factors are currently included in the questionnaire, it would be possible to carry out sophisticated multivariate analyses to control for confounding variables. Moreover, the large number of respondents would allow for exploration of relatively rare outcomes.

The NPHS is has limitations, however. The current questionnaire format does not allow for "objective" measurement of the physical, chemical, and biological exposures (e.g., blood lead levels, radon levels, levels of cockroach antigens). Research on these topics would not be appropriate within the NPHS. However, social, economic, and cultural characteristics of the housing and, to a lesser extent, the physical characteristics of the home, could be studied through this national longitudinal survey.

Second, researchers should seek out opportunities to conduct quasi-experimental trials in the area of housing and health. Quasi-experimental studies are studies in which a systematic shift in policy or environment subjects specific groups or populations to differing conditions. For example, researchers have studied the effect of changes in state Medicaid policies limiting coverage for prescription drugs on the subsequent rate of institutionalization among the elderly. One could easily conceive of situations in which a shift in housing policy might provide the opportunity for an analogous study. In addition, researchers could seek out situations in which resources are available to improve housing in some but not all of a group of similar communities (for example, on Aboriginal reserves). One could then examine the health status of these communities before and after the housing intervention. In this situation, the communities that receive the housinginter-vention would be considered the "treated" subjects, whereas the communities that receive no intervention are the "control" subjects.

## Problems in Measurement: Housing Indicators and Health Indicators

Many of the housing indicators relevant to this area of research are difficult to define or measure accurately, such as building type, overcrowding, and overall housing quality. Further research to develop accurate and quantitative measures of these housing dimensions is needed. In addition, certain exposures can be measured accurately but require specialized equipment or laboratory methods, such as dampness, mould, cockroach antigens, and indoor air quality. Research to identify the most cost-effective methods of measuring these housing characteristics or to develop simple and standardized measurement techniques would be helpful.

The measurement of health indicators is less problematic, as extensive research has resulted in numerous techniques for assessing the health status of large populations using surveys. It is more difficult to identify which health conditions and indicators are relevant to studies of a specific housing indicator. In some cases, the choice is clear, as in the case of the effect of indoor air quality on respiratory health. In other cases, the choice is less clear, such as the question of whether overcrowding or housing tenure affects health. This question is difficult when there is no clear mechanistic explanation linking a housing indicator to a health indicator.

Finally, research in this area must address the issue of confounding factors. Studies must try to control for factors already known to be associated with health outcomes, such as socioeconomic status or smoking.

## Qualitative Research Methods

Qualitative research differs from quantitative research in that qualitative research attempts to discern patterns in narrative data derived from intensive, open-ended interviews with a small sample of respondents. This approach, when applied rigorously to carefully collected and coded data, can lead to meaningful and important insights into the relationship between housing and health. Relatively little work has been done in this area. Our literature review identified almost no qualitative studies. Further research using qualitative techniques would complement existing knowledge, especially in complex areas such as the social aspects of housing.

## 10.3 Should Housing Interventions be Considered Health Interventions?

When asking whether housing interventions should be considered health interventions, we must acknowledge that high-quality housing for any population is a desirable social goal in itself, regardless of any possible health benefits. Improved health should be considered a collateral benefit of improved housing, not its primary justification. This situation is unlike that in most health care interventions, in which the purpose of the intervention is to improve health. With this distinction in mind, we propose that a numberof rigorous criteria should be met before a housing intervention can be identified as an effective health intervention.

First, convincing evidence from case-control, longitudinal, or quasi-experimental studies should point to a causative link between the housing factor and the health outcome.

Second, evidence from several well-designed studies should be available, rather than evidence from a single study or from several poorly designed studies. The quality of the studies should carry more weight than the number of studies performed, however, and a single well-designed trial should be given due consideration.

Third, studies should identify housing characteristics that are as specific, standardized, and quantifiable as possible.

Fourth, studies should use validated measures of health outcomes, and these health outcomes should be plausibly related to the housing factor.

Fifth, studies must control for potential confounding factors through appropriate statistical methods.

This rigorous approach should not discourage practical research into the use of housing interventions to improve health. On the contrary, our current lack of knowledge should encourage research in which housing interventions are followed by program evaluations that include health effects as a possible outcome.

If a housing intervention is found to be an effective health intervention, the next question is whether the housing intervention is cost-effective. In other words, the value of the health gain should be weighed against the cost of the intervention. These health impact analyses should be performed for housing interventions that have already been shown to be effective health interventions and a cost-effectiveness component should be included in studies of housing interventions carried out to determine their effectiveness in improving health.

In these analyses, researchers must consider the cost-effectiveness of alternative approaches, such as allocating resources to modify a housing factor, allocating resources to health care services, or using resources to improve the overall socioeconomic status of a population through economic development and direct aid. For example, a program to remove lead from housing may be effective in reducing the incidence of lead poisoning in children, but may not be as cost-effective as medical screening for elevated blood lead levels and the treatment of affected children.

Housing interventions to improve population health are most likely to have their desired effect when they target those who are at highest risk for adverse health outcomes or have the greatest exposure to the risk factor. In most cases, this means focusing on the poor. For example, one can expect greater health gains from spending $1000 to improve a substandard house on an Aboriginal reserve than spending the same amount on a middle-class house in Toronto. Thus, studies of the effectiveness and cost-effectiveness of housing as a health intervention should focus on vulnerable populations, including the poor and people living in low-quality housing. This approach would also identify the groups least likely to achieve meaningful improvements in their housing status in the absence of systematic interventions.

# 11. Conclusion

In the recently published *Encyclopedia of Housing* (Sage Publications, 1998) the entry on "Health" begins by noting that Florence Nightingale believed that the association between the quality of housing a person or family occupies and their health was "one of the most important that exists" (Lowry, 1998:209). From the perspective of the late twentieth century it is easy for us to forget all the progress that was made in public health, sanitation, building and community planning, leading to the *relatively* healthy housing and neighbourhoods that most people in countries like Canada enjoy today. This high standard of living can mask a variety of very real threats to both individual health as well as to the health of the population. It can also mask health inequalities among groups within the population. There is a tendency to focus as a society on individual determinants of health: smoking, drinking, diet and even genetics. We have also come to expect high standards of proof when it comes to identifying the causes of ill-health. "But at present," as Lowry notes, "many of us find it harder to appreciate that a link still exists between housing and health."

As this review of the literature demonstrates, the mechanisms through which specific aspects of housing affect health are extremely complicated – but they do exist. Figure 1, the "Conceptual Model of the Housing/Health Relationship," identifies the major factors and linkages. Researchers have made a great deal of progress in clarifying some of these mechanisms. In general, efforts to define these mechanisms are more advanced in relation to physical, chemical and biological exposures and physical characteristics of housing than in relation to the social, economic, and cultural characteristics of housing.

There is still a large gap in our knowledge about the links and pathways between housing, socio-economic status and health status. The socioeconomic status of a household plays a major role in both the health status of the individuals in a household and in the quality of their housing. Research has established that people with low socioeconomic status in a society tend to be less healthy and to die earlier than people with high socioeconomic status. Research on the housing/health relationship, however, needs to better establish the relative importance of different factors.

This review of the literature shows that the question "Does housing affect health?" cannot be answered in the abstract. The issue is not *whether* housing affects health but whether and *how* specific aspects of housing and its environment affects specific aspects of health. Research can answer only specific questions such as "Does damp housing, as measured objectively by humidity levels, cause an increase in the prevalence of respiratory symptoms?" Using these kinds of questions, further research can shed even more light on the housing/health relationship, leading to further improved policies, programs and regulations in both housing and health. The body of literature summarized in this review provides clear evidence that certain aspects of housing are already known to have significant health effects. Table1 provides a summary of the factors and the strength of the evidence for the relationship.

It is hoped that this review stimulates yet further progress in not only identifying but also disseminating knowledge about the housing/health relationship, thereby continuing the efforts initiated in the last century. This is a multidisciplinary task, requiring the combined expertise of medical and social science. It is not just an empirical task but also aconceptual task, given the difficult cause and effect relationships that need to be sorted out.

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